APPENDICES

A. NEXTGEN WEATHER INTEGRATION: DECISION SUPPORT TOOLS, DECISION IMPLEMENTATION PLAN AND COST PROCESSES

An analysis of the current state of weather integration was performed and this plan was developed for weather integration in six of the NextGen solution sets: Initiate Trajectory Based Operations (TBO), Increase Arrivals/Departures at High density Airports (High Density), Increase Flexibility in the Terminal Environment (Flex Term), Improved Collaborative Air Traffic Management (CATM), Increase Safety, Security and Environmental Performance (SSE), and Transform Facilities (Facilities).

For this first draft, each solution set was broken down into the strategic timeline components of Separation Management, Trajectory Management, Capacity Management, and Flight Data Management, and then further into capabilities, also identified as Operational Improvements (OIs). Each capability fell within either the near-, mid- or far-term timeframe. Capabilities in the mid-term were the focus of this effort. For reference, current TFM tools are described in Appendix E.

The expected weather and weather integration requirements of the mid-term capabilities were extracted from several different sources, including the REDAC Weather/ATM Integration report, the JPDO Weather Integration Conference report, the MITRE Initial Evolution Analysis for Achieving NAS Mid-term Operations and Capabilities report, the MIT/LL Roadmap for Weather integration into Traffic Flow Management Modernization report, the FAA Traffic Flow Management Concept Engineering Plan FY09 and the FAA Infrastructure Roadmap – Mid-term Integration Worksheets.

Beyond this, each of the writing groups added additional commentary, analysis or planning information. Interviews with JPDO WG Subject Matter Experts and FAA Solution Set Coordinators helped to extract additional capability/weather information. Assumptions were written based on viewpoints of the three Collaborative Decision Making (CDM) participants (Aircraft [PIC], AOC/FOC and Air Traffic Control [ATC]). In some cases, scenarios were created in which the use of weather information in support of the mid-term capability was explored

A-1. Initiate Trajectory Based Operations (TBO)

A-1.1 Introduction

A-1 is a work in-progress intended to help communicate and refine the developing mid-term weather integration story for the Initiate Trajectory Based Operation (TBO) solution set.

Mid-term Operational Improvement (OI) descriptions, contained here, go somewhat beyond what current NextGen and Federal Aviation Administration (FAA) documentation provide. The reason for this is to develop a more complete understanding of these OIs, so mid-term weather integration candidates can be more easily identified. The mechanism used to arrive at these extended descriptions is recorded in Section A-1.1.4. Although these extensions to mid-term capability descriptions have not yet received review and vetting, this paper provides a vehicle by which these 'assumptions' can obtain needed feedback, thereby furthering our understanding of mid-term OIs. These mid-term OIs begin the journey towards a full NextGen capability. This document describes these initial steps and their future evolution.

Graphics used herein are sourced from the Initiate TBO solution set smart sheet, as well as the scenarios developed by MITRE's Center for Advanced Aviation System Development (CAASD), as a product of the FAA Implementation and Integration (I&I) team. Additionally, the Flexible Airspace Management scenarios in Section A-1.8 are derived from the FAA's I&I scenarios. Future versions of the Joint Planning and Development Office's (JPDO) Air Traffic Management (ATM) Weather Integration Plan will benefit from increased synergy with the FAA's I&I scenario work.

A-1.1.1 Purpose

The purpose of this discussion is to support drafting of the JPDO's ATM Weather Integration Plan by:

- Identifying and describing likely TBO weather integration opportunities based on the mid-term OIs contained in the Initiate TBO solution set and
- Developing weather integration scenarios to help identify potential mid-term functional weather requirements.

This may also be useful in supporting other activities such as the:

- Refinement of OI descriptions in the Initiate TBO solution set,
- Scenario development by the FAA I&I team,
- Drafting of TBO white papers by the JPDO's Air Navigation Services (ANS) Working Group (WG), and
- Drafting of TBO Concept of Operations (ConOps) and Concept of Use (ConUse) documents.

A-1.1.2 Background

"TBO represents a shift from clearance-based to trajectory-based control. Aircraft will fly negotiated trajectories and air traffic control 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 trajectory-based operations will be felt in all phases of flight planning and execution.

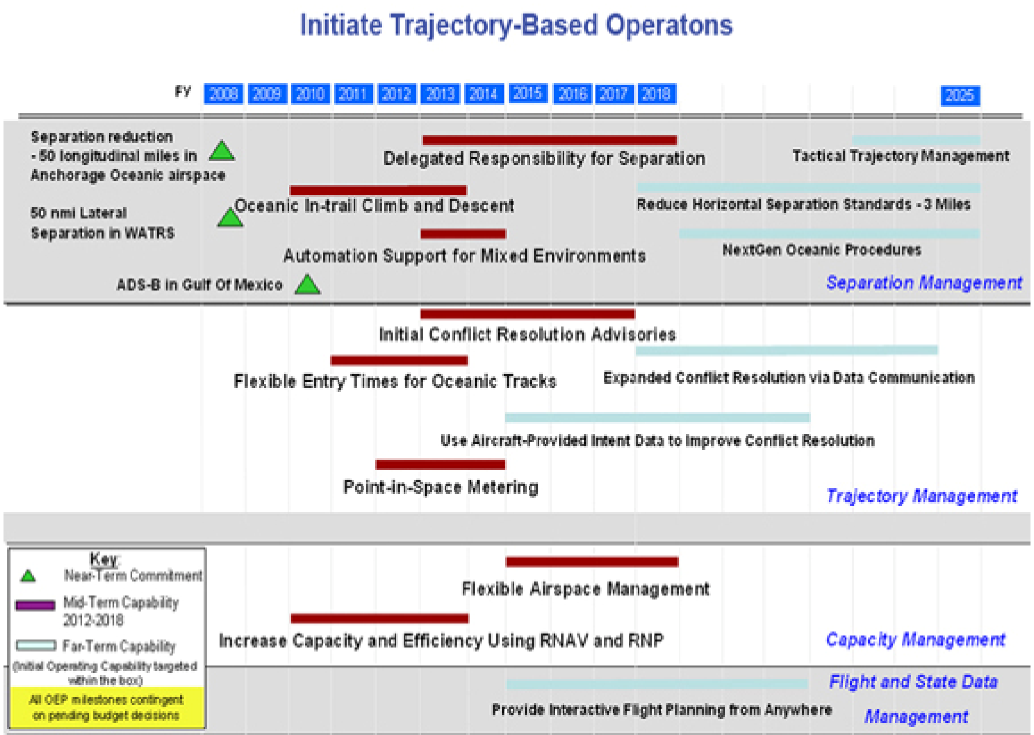
TBO is a critical NextGen capability that addresses performance gaps in the areas of capacity, productivity, efficiency, and safety. A major advantage of TBO is the ability to integrate trajectory planning, management, and execution from strategic planning to tactical decision-making. Strategic aspects of trajectory management include the planning and scheduling of flights and the corresponding planning and allocation of NextGen resources to meet demand.

Overall flows are managed strategically and tactically to ensure safety, security, and efficiency of operations. Tactical components of trajectory management include the evaluation and adjustment of individual trajectories to provide appropriate access to airspace system assets (depending on aircraft capabilities) and separation assurance to ensure safe separation among all aircraft. The flexible management of aggregate trajectories enabled by TBO allows maximum access for all traffic, while giving advantage to those aircraft with advanced capabilities that support the ATM system.

TBO represents a shift from clearance-based control to trajectory-based control. In the new high-performance ATM environment, aircraft will transmit and receive precise digital data to include aircraft routes and the times aircraft will cross key points in the airspace." [Initiate TBO Solution Set Smart Sheet, 2008]

The OIs of interest here are listed here and appear in the Initiate TBO roadmap figure below:

- Delegated Responsibility for Separation
- Oceanic In-trail Climb and Descent
- Automation Support for Mixed Environments
- Initial Conflict Resolution Advisories
- Flexible Entry Times for Oceanic Tracks
- Point-in-Space Metering
- Flexible Airspace Management
- Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigational Performance (RNP)



A-1.1.3 Definitions

This section defines key processes and terms used in this section.

Concepts

"**Trajectory Operations** is the concept of an air traffic management system in which every aircraft that is operating in and managed by the system is represented in the system via a four dimensional trajectory (4DT). Every managed aircraft known to the system has a 4DT either provided by the user or derived from a flight plan or the type of operation. Increasingly, the trajectories used are much more accurate than those in use today. High performing aircraft are flying the trajectory via their Flight Management System (FMS), using more precise navigation capabilities. The nature of the aircraft's adherence to the trajectory is based on the aircraft's capabilities and the type of operation being conducted. In this way, operations are performance based; meaning that improved services are available to better equipped aircraft.

The trajectories, from initial flight plans through subsequent changes, are managed, to the extent possible, through negotiations among the users and the Air Navigation Service Provider (ANSP). Trajectories are used for advisory services, airspace security, and separation and congestion management. Any changes to the flight (aside from time critical safety clearances) are communicated through or to the trajectory. To be effective, the trajectory must be maintained and updated at all times to reflect the latest flight plan, intent information, or clearance. During pre-flight, the users share trajectory intent information with the ANSP and have improved awareness of current and predicted availability of National Airspace System (NAS) resources, including expected constraint information. The ANSP aggregates the trajectory intent information across all user classes for improved planning. The resulting negotiated trajectory reflects user intent and provides a common basis for access to resources and knowledge of system constraints. In flight, the trajectory is used to manage separation by problem detection/resolution automation (either flight deck or ground-based). Throughout the day, the trajectories are aggregated by ANSP flow management automation to assess potential congestion problems, evaluate alternatives collaboratively, and then implement strategies with aircraft specific clearances. After flight completion, trajectories are used for post analysis and monitoring of system performance by the ANSP and by the users. At the end of the mid-term, initial applications such as paired approaches, pair-wise delegated separation, and Required Time of Arrival (RTA) clearances will be available.

Trajectory Operations are enabled by improved utilization of current and emerging aircraft capabilities (for example, Area Navigation/Required Navigation Performance [RNAV/RNP], FMS, Automatic Dependent Surveillance - Broadcast mode [ADS-B], and data communications), and improvements in ground automation/infrastructure (for example, data communications, surveillance, net-centric data operations, and ANSP and Flight Operations Center [FOC] automation). These enablers result in increased accuracy of the aircraft surveillance information, increased accuracy in navigation of the intended path, increased accuracy and reduced workload for communication, and increased accuracy in executing an Air Traffic Control (ATC) clearance or meeting an aircraft specific flow constraint. As a result, the trajectory is more accurate in execution and more predictable in time and position. These improvements are leveraged through system-wide sharing of information with all authorized users via net-centric data operations and data communications with the aircraft through ATC or AOC/FOCs. Better information and seamless information access provide the users and operators of the NAS with common awareness, a more accurate view of the system, and improved decision making." [Draft definition prepared by MITRE/CAASD staff in support of Trajectory Operations (TOps) concept development]

Processes

Identification of candidate weather integration into Decision Support Tools (DST) involves linking an aviation decision making process, algorithm, or decision aid with an operational need for weather information, for example:

- Operational air traffic recommendations such as airport configuration change options are associated with changing weather conditions (e.g., wind shifts),
- Calculations such as trajectory estimation need to incorporate the impacts of weather on flight performance and speed,
- Airspace and airport capacity prediction are impacted by both severe and routine weather (e.g., thunderstorms, obstructions to vision, winds), and
- Visual aids to decision making such as traffic displays require weather information be overlaid to identify constraints to flights and traffic flows.

Description of candidate weather integration goes on to describe in more detail the role weather plays in these decisions, for example with respect to high density airports:

- From historical Aviation System Performance Metrics (ASPM) data, empirical analysis can identify weather-parameter thresholds (e.g., winds) that identify historical runway configuration usage. These thresholds can then be used by DST algorithms to identify and recommend operational runway configurations based on current weather conditions;
- Integration of weather information into sophisticated trajectory estimation algorithms can be used to recommend a Controlled Time of Arrival (CTA) to a metering fix in support of high density airport operations:
  - Detailed “Big Airspace” terminal wind fields (particularly near merge points and the jet stream’s edge),
  - Temperature and barometric pressure profiles (used to calculate geometric altitude), and
  - Icing and turbulence (because of their impact on aircraft performance).

Terms

- 4 Dimensional Trajectory (4DT) is a series of points from departure to arrival representing the aircrafts’ path in four dimensions: lateral (latitude and longitude), vertical (altitude), and time.
- Trajectory Based Operations (TBO) is the set of NextGen capabilities for Traffic Flow Management (TFM) by trajectory, which may exist at many levels of complexity from today’s flight plans through NextGen’s high density operations. TBO capabilities are present in multiple FAA Solution Sets, including Initiate TBO, Increase Arrivals/Departures at High-Density Airports, Increase Flexibility in the
- Terminal Environment, and Improved Collaborative ATM (C-ATM).
- Initiate TBO Solution Set refers to the FAA organization that is responsible for implementing the en route portion of TBO. This should not be confused with the total set of NextGen OIs that in some way involve TBO. TBO-related OIs are also found in other Solution Sets (e.g., Increase Arrivals/Departures at High-Density Airports, Increase Flexibility in the Terminal Environment, and Improved Collaborative Air Traffic Management).
- 4-dimensional (4-D) Weather (Wx) Single Authoritative Source (SAS) is one or more 4-D grid(s) of the ‘best’ representation of ATM aviation-specific observations, analyses, and forecasts (including probability) and climatology organized by 3-Dimensional (3-D) spatial and time components (x, y, z, t) that supports NextGen ATM aviation decision making.
- 4-D Wx Data Cube is a 4-D grid of aviation-specific weather observations, analyses, and forecasts organized by 3-D spatial and time components (x, y, z, and t). The data

in the cube is used to develop the 4-D Wx SAS that supports NextGen air traffic management decision making. The 4-D Wx Data Cube is the distributed collection of all relevant aviation weather information formed from the merger of observations, automated gridded products, models, climatological data, and human forecasters input from both public and private sources. The production of the 4-D Wx Data Cube, and its utilization by NAS users' applications in an integrated, operational manner, is the essence of NextGen weather capabilities.

A-1.1.4 Methodology

In order for the JPDO to identify and describe potential candidates for mid-term weather integration into DSTs, it is essential that the corresponding OIs are first clearly and thoroughly understood. Therefore, the first step in ATM-weather integration planning is to study the descriptions of the eight Initiate TBO mid-term OIs listed in Section A-1.1.2. Our examination found these descriptions did not provide sufficient detail to support our purpose. Additionally, we found instances in which the descriptions were somewhat ambiguous and/or confusing. A subsequent review of a broad range of NextGen documentation added little to our knowledge of these eight OIs. It should be noted, later this year, the JPDO ANS WG may draft white papers for the mid-term OIs in the Initiate TBO, Increase Arrivals/Departures at High-Density Airports, Increase Flexibility in the Terminal Environment, and Improved Collaborative Air Traffic Management solution sets. This would probably provide the JPDO ATM-weather integration team with the correct level of understanding of the Initiate TBO mid-term OIs, but it would come too late to meet our work schedule for FY09 (i.e., v1.0 by September 30, 2009). Having discovered the information we require to perform our task did not yet exist, we set out to expand upon our understanding of the existing OI descriptions through discussions with TBO Subject Matter Experts (SME). Our first step was to form a discussion group of these SME to clarify and extend our understanding of the TBO mid-term OIs. This group included: key JPDO ANS and Weather WG members, JPDO ATM Weather Integration Plan writing staff, the coordinator of the Initiate TBO solution set, and MITRE staff developing scenarios for the FAA I&I team. Over several months, we discussed each of the eight mid-term TBO OIs to enhance the OI descriptions to a point where weather-related decisions became more obvious, and we could proceed to identify and describe potential weather integration candidates.

A-1.1.5 Outline

Sections A-1.2 through A-1.9 apply this methodology to each of the eight mid-term OIs listed above for the Initiate TBO solution set. These sections document OI goals, needs/shortfalls, descriptions, and design/architecture; develop assumptions as to what these OIs really intend; identify and describe 'potential' candidates for weather integration; develop scenarios; and identify weather needs. Section A-1.10 provides weather integration findings, conclusions and recommendations across the Initiate TBO solution set.

A-1.2 Delegated Responsibility for Separation (OI-0355, NAS OI-102118)

A-1.2.1 Major Mid-term Goals

The goal of Delegated Responsibility for Separation is to extend today's visual flight rules capabilities for clear weather, pair-wise, "in sight" delegated separation to operations conducted in Instrument Meteorological Conditions (IMC) leveraging ADS-B, Cockpit Display of Traffic Information (CDTI), and improved avionics.

A-1.2.2 Mid-term Operational Needs/Shortfalls

"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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.2.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.2.3.1 are direct quotes from NextGen documents and those in Section A-1.2.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.2.3.2 are only assumptions.

A-1.2.3.1 Documented 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 recommended by the controller. Delegated separation operations include separation authority for a specific maneuver (e.g., in-trail arrival). For aircraft not delegated separation authority, ANSP automation still manages separation. Aircraft performing delegated separation procedures separate themselves from one another." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.2.3.2 Capabilities Clarified

It is assumed the mid-term OI, Delegated Responsibility for Separation, 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’. This 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 and 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-1.2.4 Mid-term Design/Architecture

“New procedures permit air traffic controllers to authorize separation responsibility to pilots when it is operationally beneficial. Decision support tools are available to manage delegated separation. Key Enabling Programs include:

- En Route Automation Modernization Mid-Term work package (2013-2017).

To participate in this limited delegated separation, the lead aircraft must be equipped with ADS-B (Out), in compliance with the FAA’s Notice of Proposed Rulemaking. The secondary aircraft must be equipped with an ADS-B (In) capability on the same frequency. The following aircraft must also be equipped with a CDTI and a display of the distance to the lead aircraft in the primary field of view.” [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.2.5 Mid-term Candidate Weather Integration

It is thought that Delegated Responsibility for Separation will not include any direct weather integration. Although, 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 an essential enabler.

A-1.2.6 Linkage to Near- and Far-term

The mid-term OI, Delegated Responsibility for Separation, is a first step towards a full NextGen capability. Table A-1.2.6 describes this initial step, links it back to today’s capabilities and commitments, and describes its future evolution. Section A-1.2.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.2.8 to assist us in identifying mid-term weather needs.

Table A-1.2.6 Delegated Responsibility for Separation – Linkage to Near- and Far-term
Near –Term a) TBD
Mid-Term (Transition to NextGen)

a) Extend today's clear weather, pair-wise, 'in-sight' delegated separation operations to IMC, for example, allow delegated pair-wise separation to an aircraft following a 'pathfinder' through an area of convective weather

b) Weather common situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS).

Far-Term (Full NextGen)

a) OI-0363: Delegated Separation - Complex Procedures

b) OI-0343: Reduced Separation – High Density En Route, 3-mile

c) OI-0362: Self-Separation Airspace Operations

d) OI-0348: Reduce Separation – High Density Terminal, Less Than 3-miles

e) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced.

f) Weather OIs also evolve in the far-term to include:

- NAS OI-103121: Full (2016-2025) Improved Weather Information and Dissemination
  - Improved common weather situational awareness between the ground and air may become even more important as delegated separation procedures extend duration in the far-term.

A-1.2.7 Mid-term Operational Scenarios

This section contains the following scenarios:

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

A-1.2.7.1 Delegated Responsibility for Pair-Wise Separation in Cloud

Step 0: Pilot files a flight plan, which includes flight plan 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: Controller, when the maneuver is complete, terminates the pilot delegated separation responsibility and assumes separation responsibility

A-1.2.7.2 Delegated Responsibility for Pair-Wise Separation in Airspace Impacted by Convective Weather

Step 0: Pilot files a flight plan, which includes flight plan 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-1.2.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.2.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-1.2.8 *Delegated Responsibility for Separation* – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Wx Information Gap	Recommendations
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	N/A

A-1.3 Oceanic In-trail Climb and Descent (NAS OI-102108)

A-1.3.1 Major Mid-term Goals

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.

A-1.3.2 Mid-term Operational Needs/Shortfalls

“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.” [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.3.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.3.3.1 are direct quotes from NextGen documents and those in Section A-1.3.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.3.3.2 are only assumptions.

A-1.3.3.1 Documented 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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.3.3.2 Capabilities Clarified

The mid-term OI, Oceanic In-trail Climb and Descent, is a capability that 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-1.3.4 Mid-term Design/Architecture

"Tools and procedures, for both aircrew and ground-based system will be needed to assist the controller in managing the delegation process. Procedures will be developed for the controllers that use surveillance information and Controller Pilot Data Link Communications (CPDLC) capability. Key Enabling Programs include:

- Advanced Technologies and Oceanic Procedures Technical Refresh (2008–2010)." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.3.5 Mid-term Candidate Weather Integration

It is thought that Oceanic In-trail Climb and Descent will neither include any weather integration nor any new weather requirements.

A-1.3.6 Linkage to Near- and Far-term

The mid-term OI, Oceanic In-trail Climb and Descent, is a first step towards a full NextGen capability. Table A-1.3.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-1.3.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.3.8 to assist us in identifying mid-term weather needs.

Table A-1.3.6 ***Oceanic In-trail Climb and Descent*** **– Linkage to Near- and Far-term**
Near –Term a) Separation reduction – 50 longitudinal miles in Anchorage Oceanic airspace b) 50 nm lateral separation in West Atlantic Route System (WATRS)
Mid-Term (Transition to NextGen) p) Take advantage of improved communication, navigation, and surveillance coverage in the oceanic domain to allow participating aircraft to fly more advantageous trajectories with in-trail climb and descent maneuvers
Far-Term (Full NextGen)

a) OI-0359: *Self-Separation Airspace - Oceanic*

A-1.3.7 Mid-term Operational Scenarios

There are no applicable weather-related scenarios for *Oceanic In-trail Climb and Descent*.

A-1.3.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.3.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

We have yet to identify any weather integration or weather information needs for *Oceanic In-trail Climb and Descent*.

Table A-1.3.8 *Oceanic In-trail Climb and Descent* – Mid-term Weather Needs Analysis

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

A-1.4 Automation Support for Mixed Environments (OI-0349, NAS OI-102137)

A-1.4.1 Major Mid-term Goals

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

A-1.4.2 Mid-term Operational Needs/Shortfalls

"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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.4.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.4.3.1 are direct quotes from NextGen documents and those in Section A-1.4.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.4.3.2 are only assumptions.

A-1.4.3.1 Documented Capabilities

"The ANSP automation provides the controller with tools to manage aircraft in a mixed navigation and wake performance environment. 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 advanced capabilities (e.g., delegated self-separation maneuvers, equipped vs. non-equipped aircraft, RNAV, RNP, and trajectory flight data management). These enhancements enable ANSP to manage the anticipated increase in complexity and volume of air traffic." [Initiate TBO Solution Set Smart Sheet, 2008]

"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." [NextGen Integrated Work Plan (IWP) v1.0, 2008]

A-1.4.3.2 Capabilities Clarified

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 capability, 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 will need to 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 voice-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-1.4.4 Mid-term Design/Architecture

"En route decision support tools will be enhanced and the Human-Computer Interface designed to provide the ANSP with situational awareness to manage traffic with mixed equipage environment. The En Route Automation Modernization (ERAM) conflict alert and problem prediction capabilities will be augmented with additional algorithms to account for mixed equipage capabilities. Key Enabling Programs include:

- En Route Automation Modernization Mid-Term Work Package 2013-2017 and
- Key Decision #31 En Route Automation Modernization Mid-Term Work Package final investment decision (2011)."

[Initiate TBO Solution Set Smart Sheet, 2008]

A-1.4.5 Mid-term Candidate Weather Integration

The new capability represented by Automation Support for Mixed Environments (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, not this one.

A-1.4.6 Linkage to Near- and Far-term

The mid-term OI, Automation Support for Mixed Environments, is a first step towards a full NextGen capability. Table A-1.4.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-1.4.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.4.8 to assist us in identifying mid-term weather needs.

Table A-1.4.6 ***Automation Support for Mixed Environments*** **– Linkage to Near- and Far-term**
<u>Near –Term</u> a) TBD
<u>Mid-Term (Transition to NextGen)</u> a) Automation enhancements provide ANSP with situational awareness of aircraft with advanced capabilities (e.g., delegated self-separation maneuvers, equipped vs. non-equipped aircraft, RNAV, RNP, and trajectory flight data management) b) Automation provides the controller with tools to manage aircraft in a mixed navigation and wake performance environment.
<u>Far-Term (Full NextGen)</u> a) None

A-1.4.7 Mid-term Operational Scenarios

There are no applicable weather-related scenarios for Automation Support for Mixed Environments.

A-1.4.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.4.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

We have yet to identify any weather integration or weather information needs for Automation Support for Mixed Environments

Table A-1.4.8 ***Automation Support for Mixed Environments*** **– Mid-term Weather Needs Analysis**

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

A-1.5 Initial Conflict Resolution Advisories (NAS OI-102114)

A-1.5.1 Major Mid-term Goals

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.

A-1.5.2 Mid-term Operational Needs/Shortfalls

"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 User Request Evaluation Tool (URET) notifies the en route controller of predicted problems, but trial planning for developing resolutions is workload intensive." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.5.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.5.3.1 are direct quotes from NextGen documents and those in Section A-1.5.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.5.3.2 are only assumptions.

A-1.5.3.1 Documented Capabilities

"The ANSP conflict probe is enhanced not only to recognize conflicts but 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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.5.3.2 Capabilities Clarified

The documented description of Initial Conflict Resolution Advisories, cited above in A-1.5.3.1, makes no mention of weather. Therefore, it appears this operational improvement 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. As stated in A-1.5.1, the goal of Initial Conflict Resolution Advisories is to reduce workload. However, 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-1.5.4 Mid-term Design/Architecture

"A problem resolution capability based on the ERAM trajectory modeler will be added. Problem prediction will have migrated from the URET display to the display at the Radar Controller position. If air-ground data communication is available during this timeframe, it will be integrated with this capability to allow the ANSP to transmit the clearance (based on the resolution advisory) to capable aircraft. Key Enabling Programs include:

- En Route Automation Modernization mid-term work package (2013-2017)."

[Initiate TBO Solution Set Smart Sheet, 2008]

A-1.5.5 Mid-term Candidate Weather Integration

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
  - 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
- Return to aircraft's original flight plan when convective weather rapidly and unexpectedly improves

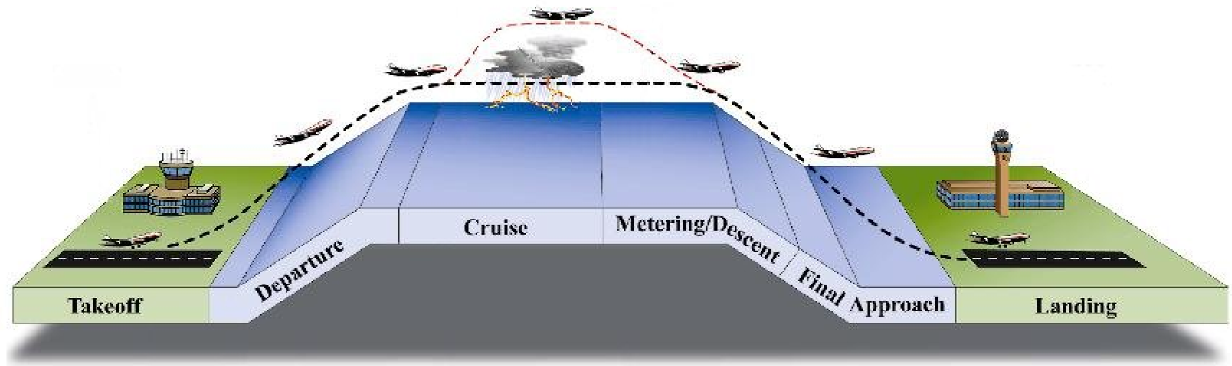
A-1.5.6 Linkage to Near- and Far-term

The mid-term OI, Initial Conflict Resolution Advisories, is a first step towards a full NextGen capability. Table A-1.5.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-1.5.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.5.8 to assist us in identifying mid-term weather needs.

Table A-1.5.6 *Initial Conflict Resolution Advisories* – Linkage to Near- and Far-term
Near –Term a) UAS- 4-D Trajectory-based Demonstration
Mid-Term (Transition to NextGen) a) Integrate existing aircraft-to-aircraft conflict detection and trial flight planning capabilities with those for conflict resolution advisory and ranking, and introduce data link clearances b) Suggest expanding the scope of this capability to include aircraft-to-weather problem detection and resolution advisory and ranking
Far-Term (Full NextGen) a) NAS OI-xxxxxx: *Use of Aircraft-Provided Intent Data to Improve Conflict Resolution* b) NAS OI-xxxxxx: *Expanded Conflict Resolution via data Communic*ations c) OI-0360: *Automation-Assisted Trajectory Negotiation* d) OI-0358: *Trajectory Flight Data Management* e) OI-0370: *Trajectory-Based Management- Full Gate-to-Gate* f) OI-0369: *Automated Negotiation/Separation Management* g) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced. h) Weather OIs also evolve in the far-term to include: • NAS OI-103119a: *Full (2016-2025) Integration of Weather Information into NAS Automation and Decision Making* • NAS OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-1.5.7 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.



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

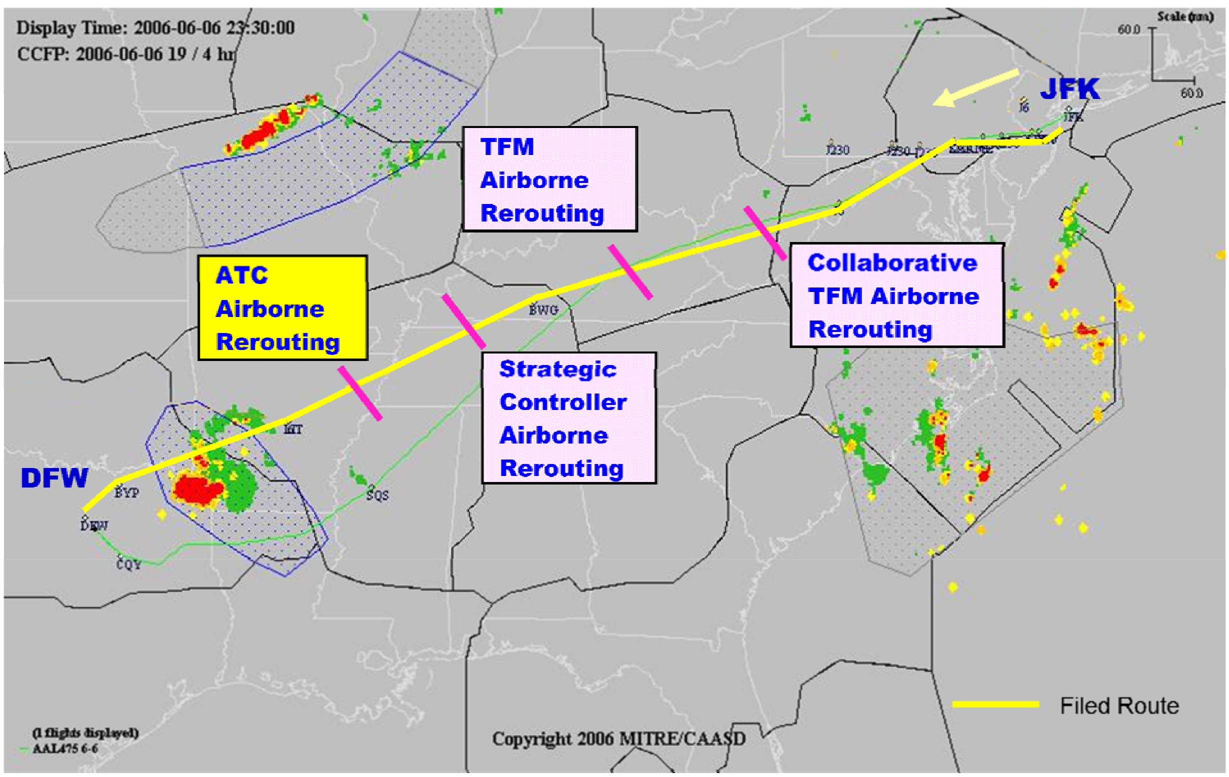
No Weather Problem Capability

- 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 the figure below 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 Traffic Management Coordinator (TMC) collaborates with FOCs 2-6 hours out to plan flows through or around the weather. 1-2 hours out, when there is sufficient confidence in the weather forecasts, planned flows around the weather are implemented. 20-40 minutes out, the strategic controller in coordination with the TMC adjusts the flows, as weather forecast updates require. 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.



A-1.5.7.1 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 his 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 Decision Support (DS) determines the flight paths of two aircraft will come into conflict 10 minutes out.

Step 2: ATC aircraft-to-aircraft conflict resolution DS, 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 DS 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 DS 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.

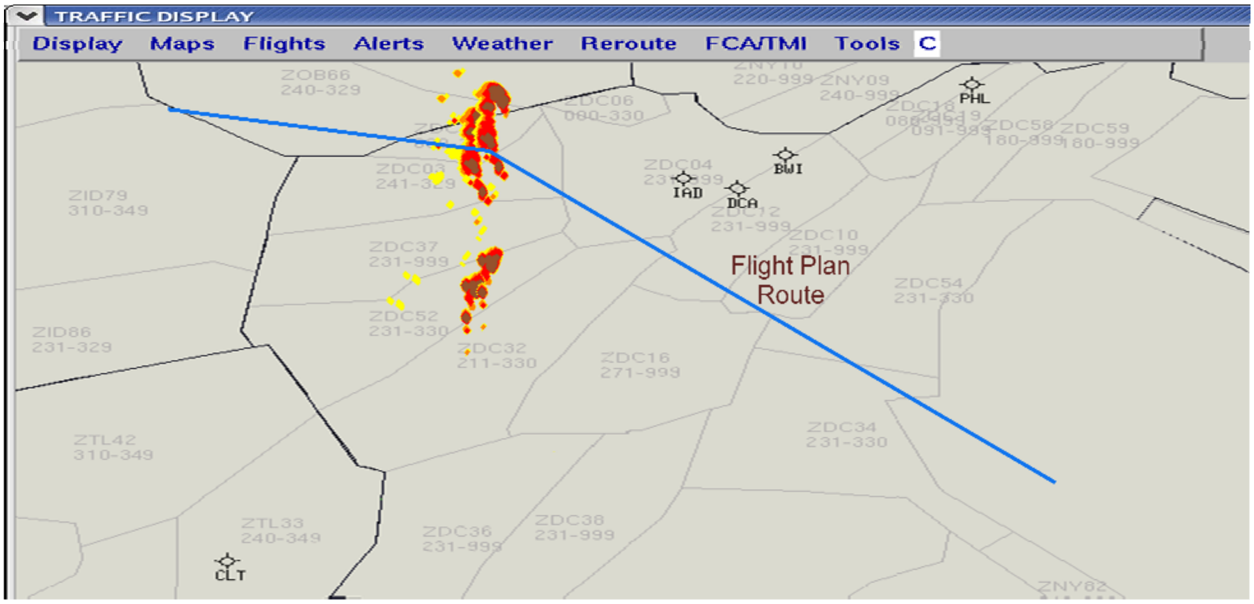
Step 6: The pilot accepts the controller's aircraft-to-aircraft conflict resolution.

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

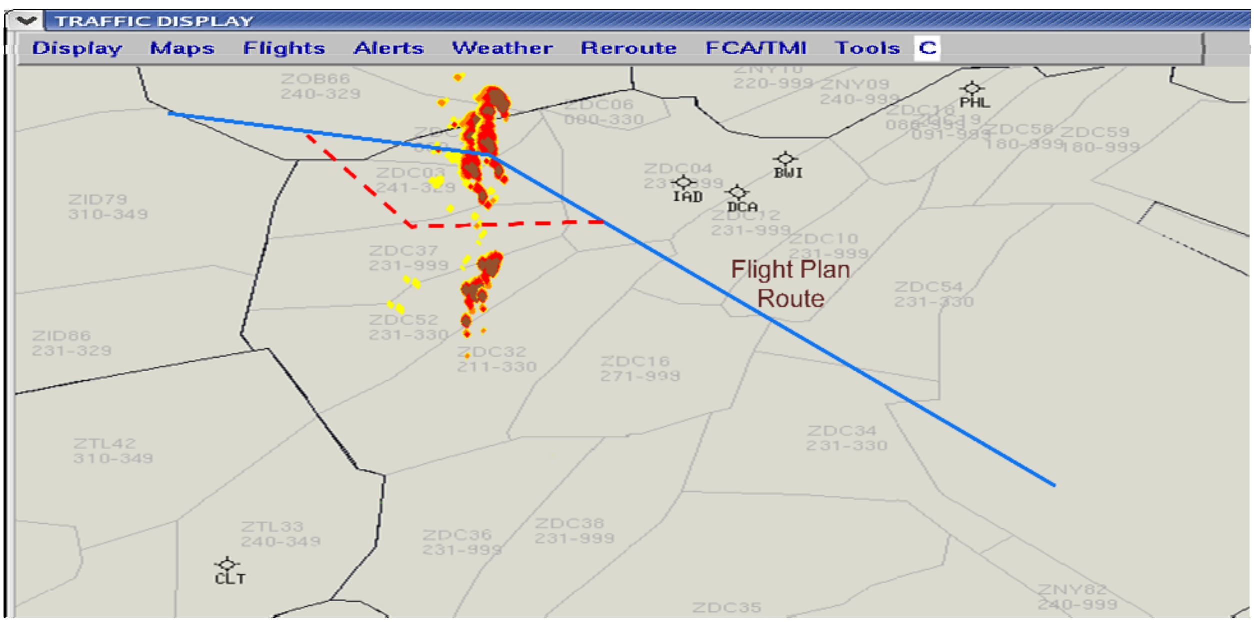
A-1.5.7.2 Controller uses weather problem detection decision support to evaluate a pilot requested maneuver around the weather to ensure it will not send the aircraft into another area of convection not yet visible on the aircraft's airborne radar

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 his 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.



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.



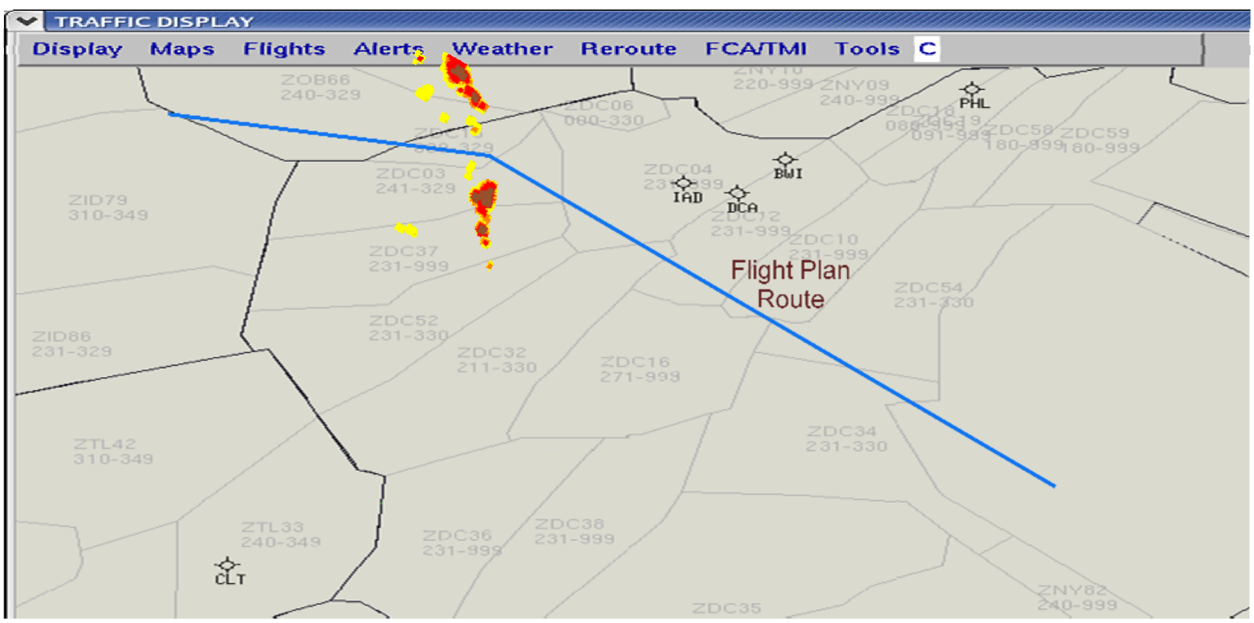
Step 3: ATC DS, integrated with a weather problem detection capability, assesses the pilot's data link requested maneuver to identify potential aircraft-to-aircraft conflicts, as well as any aircraft-to-weather problems; none are found.

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

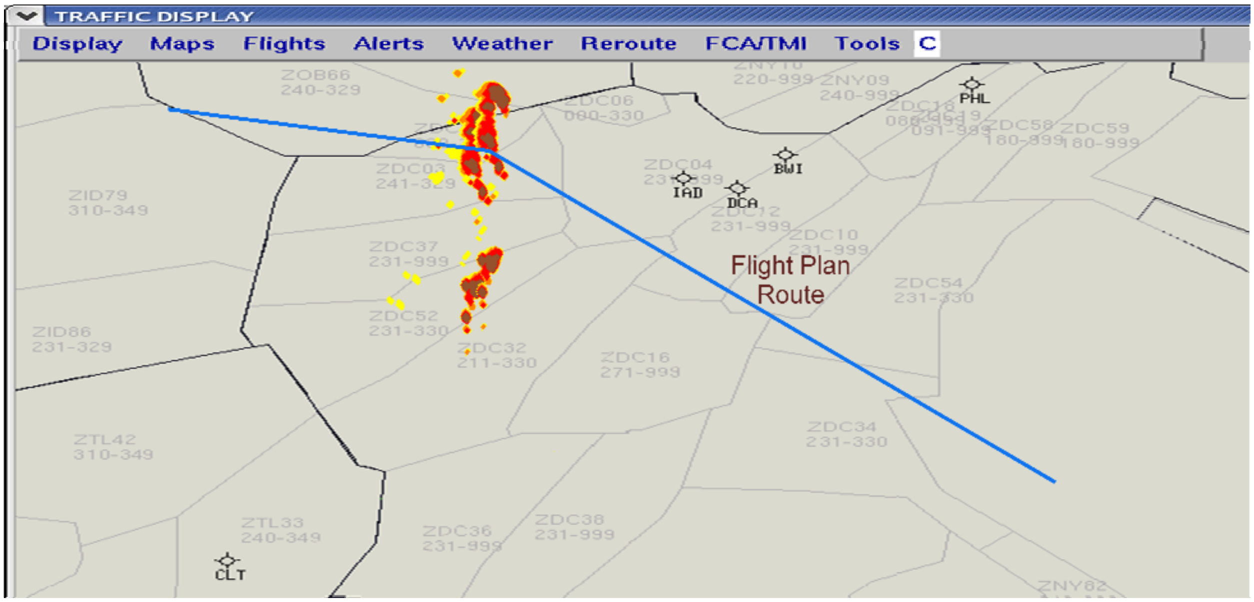
Step 5: The pilot accepts the clearance and enters the new trajectory into the aircraft's FMS.

A-1.5.7.3 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 his 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 DS, initiates a flow of aircraft through a gap in the forecasted convective weather. 30 minutes prior to an aircraft's encountering of the weather, the strategic controller, using the 4-D Wx SAS integrated with TFM DS, adjusts the flow to compensate for changes in the forecast.



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.



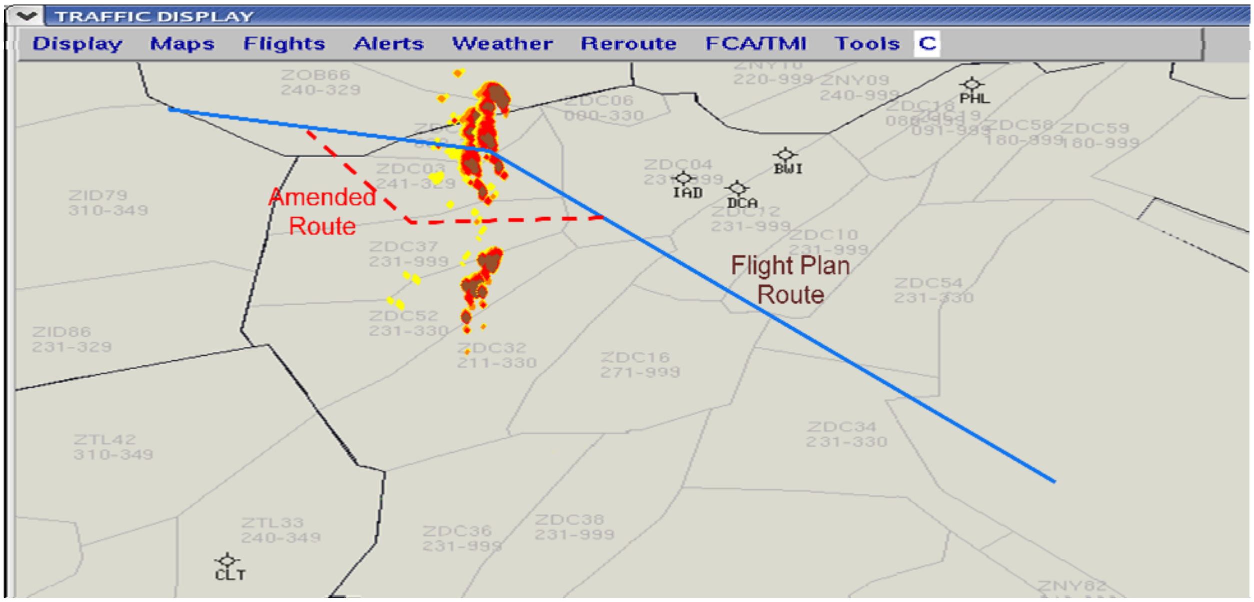
Step 2: TFM DS identifies the weather problem and alerts the appropriate TMC and strategic controller, providing them with assistance in adjusting the flow for upstream aircraft towards the new gap in the weather.

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

Step 4: ATC DS translates 4-D Wx SAS convective weather forecast information into operational impact, taking weather uncertainty into account. Using this impact information, ATC DS 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.

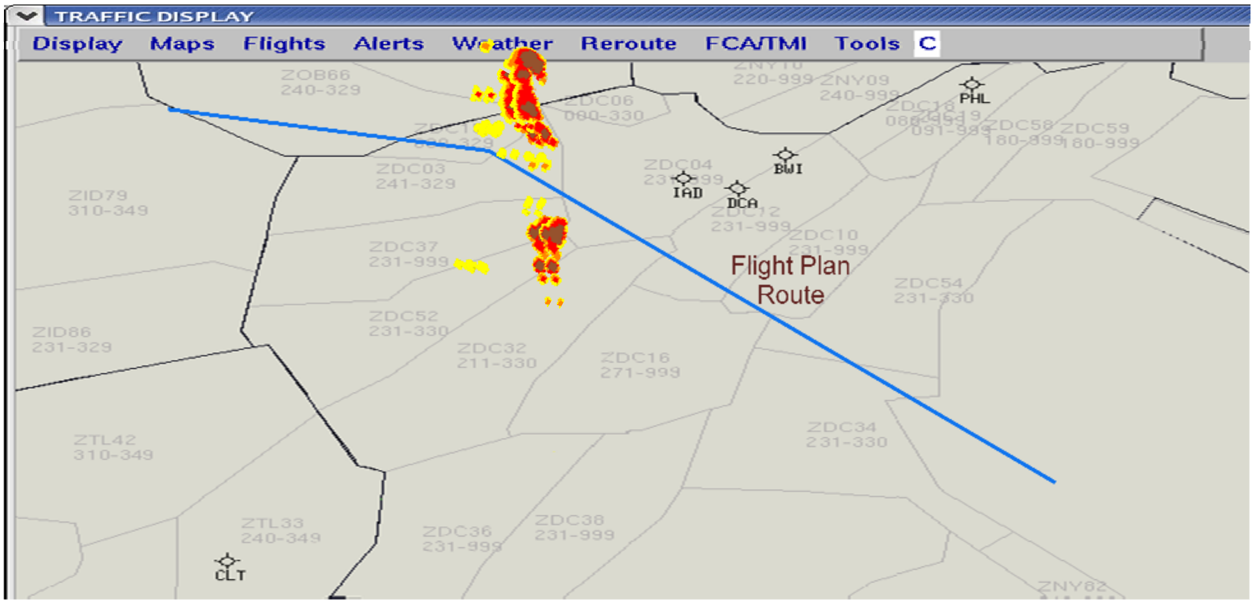
Step 6: The pilot accepts controller's suggested weather problem resolution.



Step 7: The pilot enters the new trajectory into the aircraft's 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-1.5.7.4 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

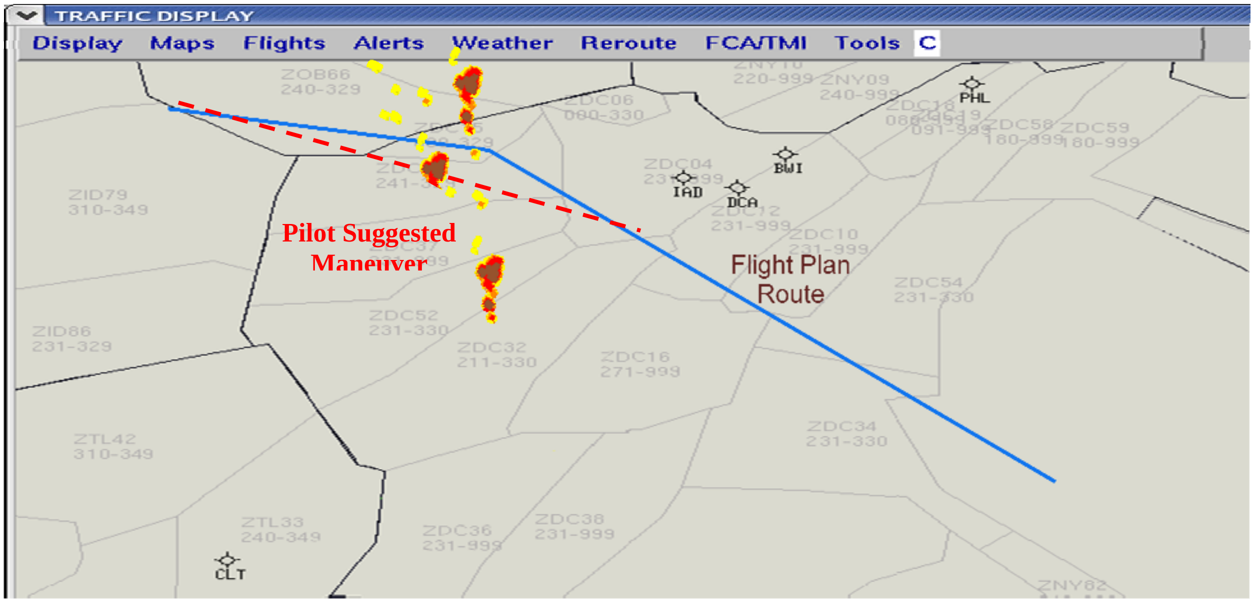
Step 0: The 4-D Wx SAS provides ANSP, ATM automation, and users with a common weather picture. The pilot also has on-board weather radar and may have access to commercially obtained weather forecasts; additionally the aircraft has data link. The pilot is responsible for keeping his aircraft a safe distance 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 DS, initiates a flow of aircraft through a gap in the forecasted convective weather. 30 minutes prior to an aircraft's encountering of the weather, the strategic controller, using 4-D Wx SAS integrated with TFM DS, adjusts the flow to compensate for changes in the forecast.



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 DS alerts the appropriate TMC and strategic controller 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 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.

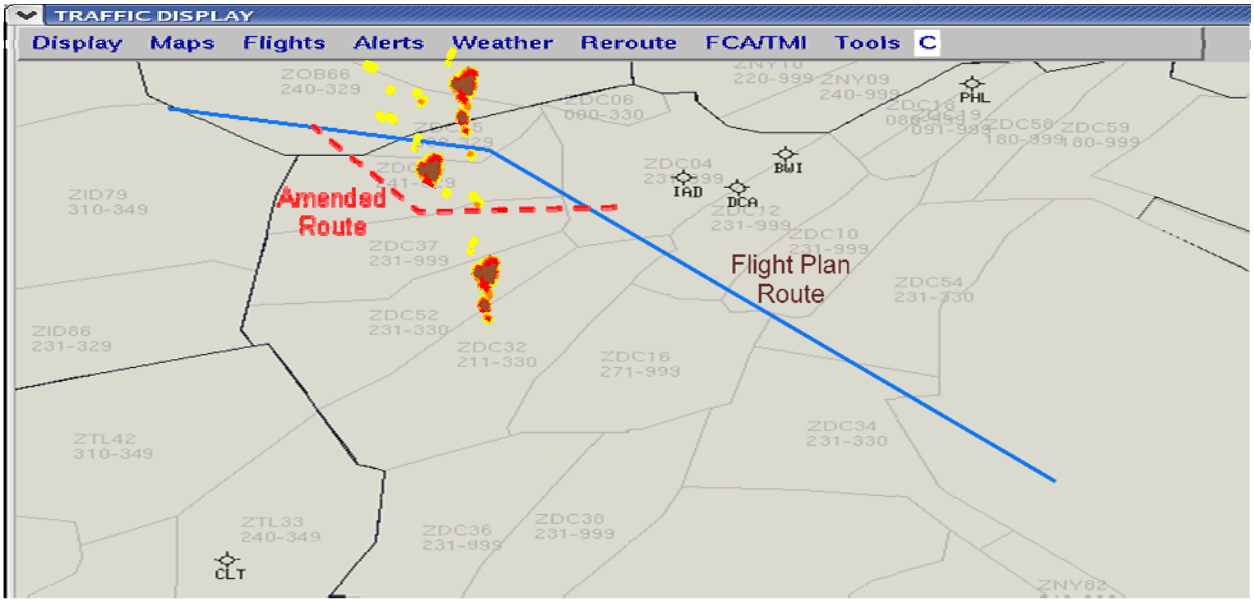


Step 4: ATC DS, integrated with a weather problem detection capability, assesses the pilot data link requested maneuver to identify potential aircraft-to-aircraft conflicts, as well as any aircraft-to-weather problems; a weather problem is found.

Step 5: ATC DS, 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.



Step 8: The pilot enters the new trajectory into the FMS.

A-1.5.7.5 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-1.5.7.6 Controller Vectors an Aircraft Around a Convective Weather Cell with an Open-loop Clearance, without the need for automated decision support

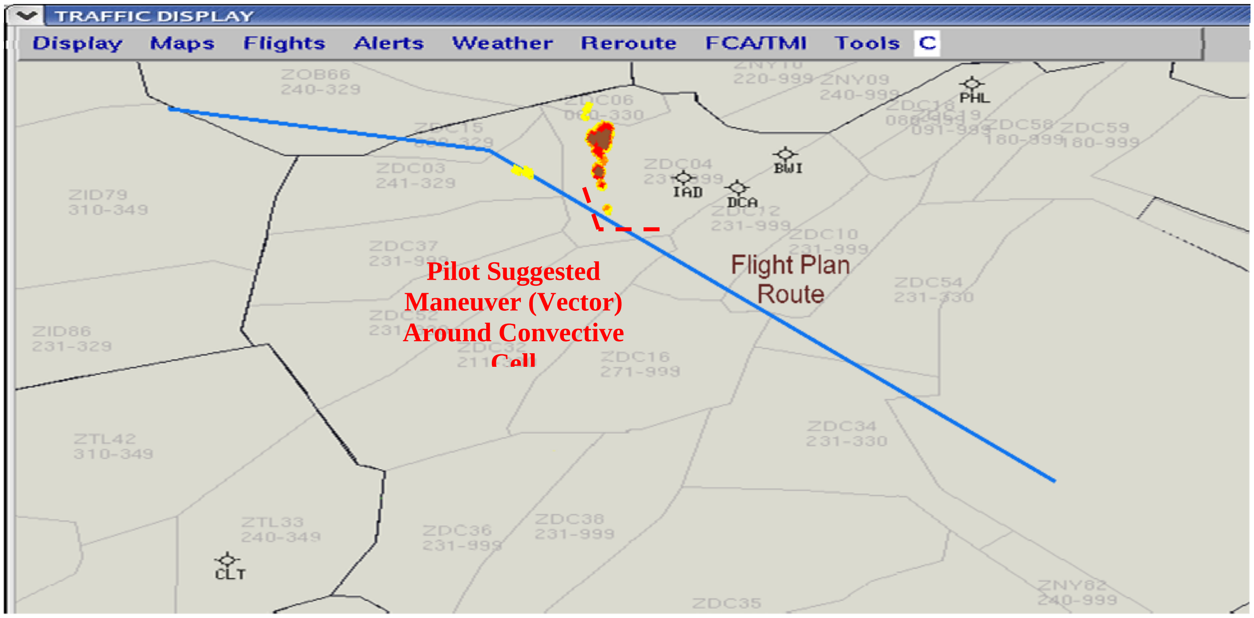
Step 0: The 4-D Wx SAS provides the sector controller and the pilot with a common weather picture. The pilot may also use on-board weather radar, as well as commercially obtained weather forecasts. An aircraft is 10 minutes out from encountering an isolated convective weather cell on its filed flight plan.

Step 1: The pilot cognitively detects the weather problem, using his 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.



A-1.5.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.5.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-1.5.8 *Initial Conflict Resolution Advisories* – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Wx Information Gap	Recommendations
None - for the aircraft-to-aircraft capability currently described	None	N/A	N/A	N/A
Suggested weather	NextGen shall provide	TBD	TBD	TBD

integration candidate Weather problem detection and resolution including: 1) NextGen shall provide ATC DS to determine the impact of weather (i.e., determine when airspace is useable and by which aircraft classes) based on pilot behavior and deterministic/probabilistic weather forecasts. This translation shall be standardized and use a common weather picture (i.e., 4-D Wx SAS). 2) NextGen shall provide ATC DS (e.g., algorithms) to proactively determine which aircraft have a weather problem. 3) NextGen shall provide ATC DS for weather problem resolution (e.g., algorithms) to generate resolution options around the weather based initially on deterministic weather forecasts (supplemented with other methodologies to address weather uncertainty) and later using probabilistic forecasts. This capability needs to be standardized and must use a common weather picture (i.e., 4-D Wx SAS). 4) NextGen shall provide a weather-related rationale along with clearances.	ATC DS 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 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 DS 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-1.6 Flexible Entry Times for Oceanic Tracks (OI-0304, NAS OI-104102)

A-1.6.1 Major Mid-term Goals

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.

A-1.6.2 Mid-term Operational Needs/Shortfalls

"The current system optimizes user efficiency subject to constraints of the current system. As fuel costs increase and as traffic increases, constraints need to be removed and traffic flows need to be improved to achieve further efficiencies (e.g., flight efficiency and system performance)." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.6.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.6.3.1 are direct quotes from NextGen documents and those in Section A-1.6.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.6.3.2 are only assumptions.

A-1.6.3.1 Documented Capabilities

"Flexible entry times into oceanic tracks or flows allow greater use of user-preferred trajectories. Under the Oceanic Trajectory Management Four Dimensional (OTM4D) 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." [Initiate TBO Solution Set Smart Sheet, 2008]

"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." [NextGen IWP v1.0, 2008]

A-1.6.3.2 Capabilities Clarified

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-1.6.4 Mid-term Design/Architecture

"Ground-based automation develops trajectory information for each aircraft and determines opportunities for increased efficiencies. Decision support tools help the controllers ensure the accuracy of the trajectories and their implications on traffic and separation. They also help identify suggested control actions to satisfy the requested 4-D trajectory and/or identify the emerging opportunities. Key Enabling Programs include:

- Advanced Technologies and Oceanic Procedures Enhancements (2013-2014)."

[Initiate TBO Solution Set Smart Sheet, 2008]

A-1.6.5 Mid-term Candidate Weather Integration

This OI needs to integrate oceanic wind forecast information with the calculation of flexible entry times for oceanic tracks. During concept development at MITRE/CAASD, it was determined there may be a need for more frequent oceanic weather forecasts, perhaps every 3 hours instead of 6, 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. These potential weather needs will be further explored in future releases of this document.

A-1.6.6 Linkage to Near- and Far-term

The mid-term OI, Flexible Entry Times for Oceanic Tracks, is a first step towards a full NextGen capability. Table A-1.6.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-1.6.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.6.8 to assist us in identifying mid-term weather needs.

Table A-1.6.6 ***Flexible Entry Times for Oceanic Tracks*** **– Linkage to Near- and Far-term**
<u>**Near –Term**</u> a) Oceanic Trajectory Management 4-D Pre-departure Tool Specification
<u>**Mid-Term (Transition to NextGen)**</u> a) Integrate oceanic wind forecast information with the calculation of flexible entry times for oceanic tracks
<u>**Far-Term (Full NextGen)**</u> a) OI-0359: *Self-Separation Airspace - Oceanic* b) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced.

c) Weather OIs also evolve in the far-term to include:
- NAS OI-103119a: *Full (2016-2025) Integration of Weather Information into NAS Automation and Decision Making*
- NAS OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-1.6.7 Mid-term Operational Scenarios

This section contains the following scenario:

Calculate flexible entry times for oceanic tracks, using forecasted oceanic winds

A-1.6.7.1 Calculate Flexible Entry Times for Oceanic Tracks, Using Forecasted Oceanic Winds

Step 0: TBD

Step 1: TBD

A-1.6.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.6.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-1.6.8 ***Flexible Entry Times for Oceanic Tracks*** **–** Mid**-term Weather Needs Analysis**

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Wx Information Gap	Recommendations
Integrate oceanic wind forecast information with the calculation of flexible entry times for oceanic tracks	Forecasted 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	TBD	TBD

	TBD *Latency TBD*			

A-1.7 Point-in-Space Metering (NAS OI-104120)

A-1.7.1 Major Mid-term Goals

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 Miles-in-Trail (MIT) constraints.

A-1.7.2 Mid-term Operational Needs/Shortfalls

"As air traffic increases, flows into constrained resources must be strategically managed to minimize individual flight as well as 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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.7.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.7.3.1 are direct quotes from NextGen documents and those in Section A-1.7.3.2 are clarifications developed via the methodology described in Section 1.4. At this point in time, the clarified capabilities in Section A-1.7.3.2 are only assumptions.

A-1.7.3.1 Documented Capabilities

"ANSP uses scheduling tools and trajectory-based operations to assure smooth flow of traffic and increase the efficient use of airspace.

Point-in-space metering can be associated with a departure fix, arrival fix, en route airspace volume or boundary, or point-in-space. Decision support tools will allow traffic managers to develop scheduled arrival times for constrained resources and allow controllers to manage aircraft trajectories to meet the scheduled meter times." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.7.3.2 Capabilities Clarified

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 speed clearances and transmitted to the aircraft.

Before this OI capability is applied to the current traffic, C-ATM traffic flow management 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.

A-1.7.4 Mid-term Design/Architecture

"Ground-based systems using system-wide shared trajectory-based operations information will create and maintain schedules at metering points and will disseminate the schedules to both air traffic controllers and to flight operators. Decisions need to be made on the allocation of functions among ERAM and Traffic Flow Management System (TFMS). Key Enabling Programs include:

- Traffic Management Advisor – NextGen,
- Key Decision #44 Implementation of Mid-term Traffic Management Advisor (TMA) (2010)
- Traffic Flight Management System Work Package (WP) 1 (2009-2011), and
- En Route Automation Modernization Release 4 (2013-2014)."

[Initiate TBO Solution Set Smart Sheet, 2008]

A-1.7.5 Mid-term Candidate Weather Integration

C-ATM traffic flow management 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 C-ATM 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 time-based metering OI: Time-Based Metering Using RNP and RNAV Route Assignments.

The CTAs generated by Point-in-Space Metering, which are used by the ANSP to provide speed clearances, 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.

A-1.7.6 Linkage to Near- and Far-term

The mid-term OI, Point-in-Space Metering, is a first step towards a full NextGen capability. Table A-1.7.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-1.7.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.7.8 to assist us in identifying mid-term weather needs.

Table A-1.7.6 ***Point-in-Space Metering*** **– Linkage to Near- and Far-term**
<u>Near –Term</u> a) Point-in-Space Metering (TMA En Route) Demonstration
<u>Mid-Term (Transition to NextGen)</u> a) Weather common situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS). b) ANSP automation calculates a sequence of ‘attainable’ upstream CTAs for an aircraft, at various airspace boundaries along a flight path, to provide smooth metering of traffic to a downstream capacity-constrained point, taking weather’s impact on aircraft speed into account. c) ANSP automation calculates the airspeed required to meet the next CTA, using weather impact information (i.e., impact on aircraft ground speed). d) The ANSP manages the aircraft by issuing speed changes, rather than employing MIT
<u>Far-Term (Full NextGen)</u> a) OI-0360/NAS OI 104105: A*utomation-Assisted Trajectory Negotiation and Conflict Resolution* b) OI-0369/NAS OI 104121: *Automated Negotiation/Separation Management* c) OI-0370: *Trajectory-Based Management – Gate-To-Gate* d) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced. e) Weather OIs also evolve in the far-term to include: • NAS OI-103119a: *Full (2016-2025) Integration of Weather Information into NAS Automation and Decision Making* • NAS OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-1.7.7 Mid-term Operational Scenarios

This section contains the following scenario:

Calculate a sequence of recommended upstream CTAs to a downstream capacity-constrained point, integrating weather and aircraft performance information, and convert these CTAs into desired airspeed changes

A-1.7.7.1 Calculate a Sequence of Recommended Upstream CTAs to a Downstream Capacity-Constrained Point, Integrating Weather and Aircraft Performance Information, and Convert These CTAs into Desired Airspeed Changes

Step 0: Weather information is made available by the NextGen net-centric 4-D Wx Data Cube and its initial 4-D Wx SAS. C-ATM Traffic Flow Management processes are used collaboratively (ANSP, AOC, FOC, and pilot) to determine aircraft’s CTA at a downstream capacity-constrained point.

Step 1: Point-in-Space Metering DS 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), Point-in-Space Metering DS uses this weather information to calculate the desired airspeed 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 speed changes.

A-1.7.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.7.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-1.7.8 *Point-in-Space Metering* – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Wx Information Gap	Recommendations
q) 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 Aloft • Hi-Res Rapid Refresh (HRRR) a) 3 km horizontal, hourly update, 15 min resolution, Continental United States (CONUS) • Rapid Update	TBD	TBD

	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*	Cycle (RUC) a) 13 km horizontal, 50 vertical levels, hourly update, 0-12 hr forecasts, CONUS • Weather Research and Forecasting - Rapid Refresh (WRF-RR) Turbulence • Analysis and 1-12hr Graphical Turbulence Guidance (GTG)		

A-1.8 Flexible Airspace Management (OI-0351, NAS OI-108206)

A-1.8.1 Major Mid-term Goals

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.

A-1.8.2 Mid-term Operational Needs/Shortfalls

"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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.8.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.8.3.1 are direct quotes from NextGen documents and those in Section A-1.8.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.8.3.2 are only assumptions.

A-1.8.3.1 Documented 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." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.8.3.2 Capabilities Clarified

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.

There appears to be a significant interaction between the Initiate TBO OI, Flexible Airspace Management, and the Improved C-ATM OI, Continuous Flight Day Evaluation. At this time, it is not clear how the potential weather integration candidate discussed in this section may be distributed across these two OIs. After more discussion, it is entirely possible (all or part of) the weather integration discussed here could be moved over to Continuous Flight Day Evaluation.

A-1.8.4 Mid-term Design/Architecture

"Tools will be developed to define and support the assessment of alternate configurations as well as re-mapping of flight information, radar information, etc., to the appropriate positions. Key Enabling Programs include:

- En Route Automation Modernization Release 3 (2011-2012),
  - Key Decision #43 En Route Automation Modernization Release 3 Package Contents (2009)
- Traffic Flow Management System WP 2 (2011-2016),
- En Route Automation Mid-term WP (2013-2017), and

- National Voice Switch (2013-2015). ”

[Initiate TBO Solution Set Smart Sheet, 2008]

A-1.8.5 Mid-term Candidate Weather Integration

Weather integration for Flexible Airspace Management includes:

- Determination of pre-defined airspace configurations, using existing traffic patterns and climatological weather
- Identification of airspace needs and development of a baseline plan for the given flight day, 1 to 5 days in advance, using forecasted weather information
- Establishment of a baseline airspace configuration for the day, 8-24 hours in advance, using forecasted weather information
- Determination of alternative airspace configurations, 4-8 hours in advance, using forecasted weather information
- Selection and implementation of specific alternatives, 1- 4 hours in advance, using forecasted weather information

A-1.8.6 Linkage to Near- and Far-term

The mid-term OI, Flexible Airspace Management, is a first step towards a full NextGen capability. Table A-1.8.6 describes this initial step, links it back to today’s capabilities and commitments, and describes its future evolution. Section A-1.8.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.8.8 to assist us in identifying mid-term weather needs.

Table A-1.8.6 ***Flexible Airspace Management*** **– Linkage to Near- and Far-term**
<u>Near –Term</u> a) TBD
<u>Mid-Term (Transition to NextGen)</u> a) Weather common situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS). b) En Route airspace designers use existing traffic patterns and climatological weather studies to generate pre-defined airspace configuration c) Traffic management Specialist (TMS), TMC, and Front Line Manager (FLM) identify airspace needs and develop baseline plan for the given flight day 1 to 5 days ahead using forecasted weather information d) TMS, TMC, strategic controller & FLM establish baseline airspace configuration of the day 8-24 hours in advance using forecasted weather information e) Strategic controller & FLM determine alternative airspace configurations 4-8 hours in advance using forecasted weather information f) TMC, strategic controller and FLM select and implement specific alternatives 1- 4

hours in advance using forecasted weather information
Far-Term (Full NextGen) a) OI-0366: *Dynamic Airspace Performance Designation* b) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced. c) Weather OIs also evolve in the far-term to include: • NAS OI-103119a: *Full (2016-2025) Initial* Integration of Weather Information into NAS Automation and Decision Making • NAS OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-1.8.7 Mid-term Operational Scenarios

This section contains the following four scenarios:

- Identify airspace needs and develop baseline plan for the given flight day, 1 to 5 days in advance, using forecasted weather information
- Establish baseline airspace configuration of the day, 8-24 hours in advance, using forecasted weather information
- Determine alternative airspace configurations, 4-8 hours in advance, using forecasted weather information
- Select and implement specific alternatives, 1- 4 hours in advance, using forecasted weather information

A-1.8.7.1 Identify Airspace Needs and Develop Baseline Plan for the Given Flight Day, 1 to 5 Days in Advance, Using Forecasted Weather Information

Step 0: Months in advance, based on historical traffic patterns and climatological weather, pre-defined routes (including RNAV and RNP routes) and pre-defined airspace configurations are defined, along with rules for their usage. At least 4 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-1.8.7.2 Establish Baseline Airspace Configuration of the Day, 8-24 Hours in Advance, Using Forecasted Weather 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 Air Traffic Control System Command Center (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 & 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 Special Activity Airspace (SAA) that may need to be traversed.

Step 5: TMCs negotiate use of SAA with appropriate agency.

A-1.8.7.3 Determine Alternative Airspace Configurations, 4-8 Hours in Advance, Using Forecasted Weather 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 Traffic Management initiatives (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-1.8.7.4 Select and Implement Specific Alternatives, 1- 4 Hours in Advance, Using Forecasted Weather 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-1.8.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.8.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-1.8.8 *Flexible Airspace Management* **– Mid-term Weather Needs Analysis**

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Data Cube Capability	Mid-Term Wx Information Gap	Recommendations
Determine pre-defined airspace configuration using existing traffic patterns and climatological weather	NAS-wide climatological weather information	No climatological weather information planned for IOC	Gaps • NAS-wide climatological weather information	TBD
Identify airspace needs and develop baseline plan for the given flight day 1 to 5 days ahead using forecasted weather 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	Gaps • Multi-hour forecasts (e.g., 3, 6 hourly) of winds aloft, icing, turbulence and convection 1 to 5 days out	TBD
Establish baseline airspace configuration of the day 8-24 hours in advance using forecasted weather 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 a) 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) Turbulence • Analysis and 1-12hr GTG	Gaps • 12-24 Turbulence Forecast	TBD

Determine alternative airspace configurations 4-8 hours in advance using forecasted weather information	Hourly forecasts of winds aloft, icing, turbulence and convection 4-8 hours out *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD*	<u>Winds Aloft</u> • 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 <u>Convection</u> • CIWS (0-2 hr) • CoSPA (2-8 hr) <u>Turbulence</u> • Analysis and 1-12hr GTG	TBD	TBD
Select and implement specific alternatives 1- 4 hours in advance using forecasted weather information	Hourly forecasts of winds aloft, icing, turbulence and convection 1-4 hours out *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	<u>Winds Aloft</u> • 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 <u>Convection</u> • CIWS (0-2 hr) • CoSPA (2-8 hr) <u>Turbulence</u> • Analysis and 1-12hr GTG	TBD	TBD

A-1.9 Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigational Performance (RNP) (OI-0311, NAS OI-108209)

A-1.9.1 Major Mid-term Goals

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, increase airspace efficiency and capacity.

A-1.9.2 Mid-term Operational Needs/Shortfalls

"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, and adjacent airport traffic flows." [Initiate TBO Solution Set Smart Sheet, 2008]

A-1.9.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-1.9.3.1 are direct quotes from NextGen documents and those in Section A-1.9.3.2 are clarifications developed via the methodology described in Section A-1.1.4. At this point in time, the clarified capabilities in Section A-1.9.3.2 are only assumptions.

A-1.9.3.1 Documented 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 Instrument Landing System (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." [Initiate TBO Solution Set Smart Sheet, 2008]

"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." [NextGen IWP v1.0, 2008]

A-1.9.3.2 Capabilities Clarified

RNAV capability allows an aircraft to fly directly point-to-point rather than following the inefficient zig-zag fixed route structure based on ground-based NAVAIDS, resulting in distance, time and cost saving 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, 3-D 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 2D 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 A-1.9.3.1, 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-1.9.4 Mid-term Design/Architecture

"RNAV will be implemented at and above flight level 180 by the end of the mid-term. RNP-2 will be implemented at and above flight level 290 by the end of the mid-term. A decision on mandating these capabilities will be made in the near-term. [Initiate TBO Solution Set Smart Sheet, 2008]

Key Enabling Programs include:

- En Route Automation Modernization Release 2 (2010-2011) and
- En Route Automation Modernization Release 3 (2011-2012)
  - Key Decision #43 En Route Automation Modernization Release 3 Package Contents (2009) " [Initiate TBO Solution Set Smart Sheet (2008)]

A-1.9.5 Mid-term Candidate Weather Integration

Identify whether fixed RNAV/RNP routes are or soon will be blocked by convective weather.

A-1.9.6 Linkage to Near- and Far-term

The mid-term OI, Increase Capacity and Efficiency Using RNAV and RNP, is a first step towards a full NextGen capability. Table A-1.9.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-1.9.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-1.9.8 to assist us in identifying mid-term weather needs.

Table A-1.9.6 ***Increase Capacity and Efficiency Using RNAV and RNP*** **– Linkage to Near- and Far-term**
<u>Near –Term</u> a) TBD

Mid-Term (Transition to NextGen)

a) Identify whether fixed RNAV/RNP routes are or soon will be blocked by convective weather

Far-Term (Full NextGen)

a) OI-0338: *Efficient Metroplex Merging and Spacing (assuming RNAV)*
b) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced.
c) Weather OIs also evolve in the far-term to include:
   - NAS OI-103119a: *Full (2016-2025) Initial Integration of Weather Information into NAS Automation and Decision Making*
   - NAS OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-1.9.7 Mid-term Operational Scenarios

This section contains the following scenario:

- Use weather information to determine availability of predefined RNAV/RNP routes

A-1.9.7.1 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 DS 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-1.9.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-1.9.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-1.9.8 ***Increase Capacity and Efficiency Using RNAV and RNP*** **– Mid-term Weather Needs Analysis**

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

A-1.10 Findings, Conclusions, and Recommendations

Much analysis and discussion are required before a final set of mid-term, Initiate TBO, weather integration candidates can be identified. From among the 'potential' weather integration candidates listed below, some may be incorporated into TBO ConOps documents, forming the basis for NextGen weather integration requirements.

A-1.10.1 Findings

To-date, the following mid-term, Initiate TBO, weather-related, operational capabilities have been identified as 'potential' candidates for inclusion into DSTs.

Initial Conflict Resolution Advisories

- Controller weather problem detection decision support to:
  - Prevent directing aircraft into hazardous weather inadvertently when resolving aircraft-to-aircraft conflicts
  - 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
- 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
  - Return aircraft to original flight plan when convective weather rapidly and unexpectedly improves

Flexible Entry Times for Oceanic Tracks

- Integrate oceanic wind forecast information with the calculation of flexible entry times for oceanic tracks

Point-in-Space Metering

- Calculation of a sequence of recommended upstream CTAs to a downstream capacity-constrained point, integrating weather and aircraft performance information, and conversion of these CTAs into desired airspeed changes

Flexible Airspace Management

- Determination of pre-defined airspace configurations, using existing traffic patterns and climatological weather
- Identification of airspace needs and development of a baseline plan for the given flight day, 1 to 5 days ahead, using forecasted weather information
- Establishment of a baseline airspace configuration for the day, 8-24 hours in advance, using forecasted weather information
- Determination of alternative airspace configurations, 4-8 hours in advance, using forecasted weather information
- Selection and implementation of specific airspace configuration alternatives, 1- 4 hours in advance, using forecasted weather information

Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigational Performance (RNP)

- Determination of whether fixed RNAV/RNP routes are or soon will be blocked by convective weather

Additionally, the following mid-term, en route TBO, weather-related, operational decisions have been identified as ‘potential’ candidates for common weather situational awareness among decision makers:

Delegated Responsibility for Separation

- Delegated responsibility for pair-wise separation in convective weather (i.e., aircraft following a ‘pathfinder’)

Initial Conflict Resolution Advisories

- Controller vectors an aircraft around a convective weather cell with an open-loop clearance

A-1.10.2 Conclusions

The authors of this document need to perform more analysis and receive more feedback on this initial version, before conclusions can be reached.

A-1.10.3 Recommendations

The authors of this document need to perform more analysis and receive more feedback on this initial version, before recommendations can be made.

A-2. Increase Arrivals/Departures at High Density Airports

A-2.1 Introduction

This Section is a work in-progress intended to help communicate and refine the developing mid-term weather integration story for the Increase Arrivals/Departures at High Density Airport solution set. Mid-term Operational Improvement (OI) descriptions, contained in this section, go somewhat beyond what current NextGen and Federal Aviation Administration (FAA) documentation provide. The reason for this is to develop a more complete understanding of these OIs, so mid-term weather integration candidates can be more easily identified. The mechanism used to arrive at these extended descriptions is documented in Section A-2.1.4. Although these extensions to mid-term capability descriptions have not yet received review and vetting, this paper provides a vehicle by which these 'assumptions' can obtain needed feedback, thereby furthering our understanding of mid-term OIs. These mid-term OIs begin the journey towards a full NextGen capability. This document describes these initial steps and their future evolution.

Graphics in this paper are sourced from the Increase Arrivals/Departures at High-Density Airports solution set smart sheet, as well as the Terminal Airspace Reconfiguration scenarios developed by MITRE's Center for Advanced Aviation System Development (CAASD), as a product of the FAA's Implementation and Integration (I&I) team.

A-2.1.1 Purpose

The purpose of this paper is to support drafting of the Joint Planning and Development Office's (JPDO) Air Traffic Management (ATM) Weather Integration Plan by:

- Identifying and describing likely high density airport weather integration opportunities based on the mid-term OIs contained in the Increase Arrivals/Departures at High Density Airports solution set and
- Developing weather integration scenarios to help identify mid-term functional weather requirements.

This section may also be useful in supporting other activities such as the:

- Refinement of OI descriptions in the Increase Arrivals/Departures at High Density Airports solution set,
- Scenario development by the FAA I&I team,
- Drafting of high density airport white papers by the JPDO's Air Navigation Services (ANS) Working Group (WG), and
- Drafting of Increase Arrivals/Departures at High Density Airports Concept of Operations (ConOps) and Concept of Use (ConUse) documents.

A-2.1.2 Background

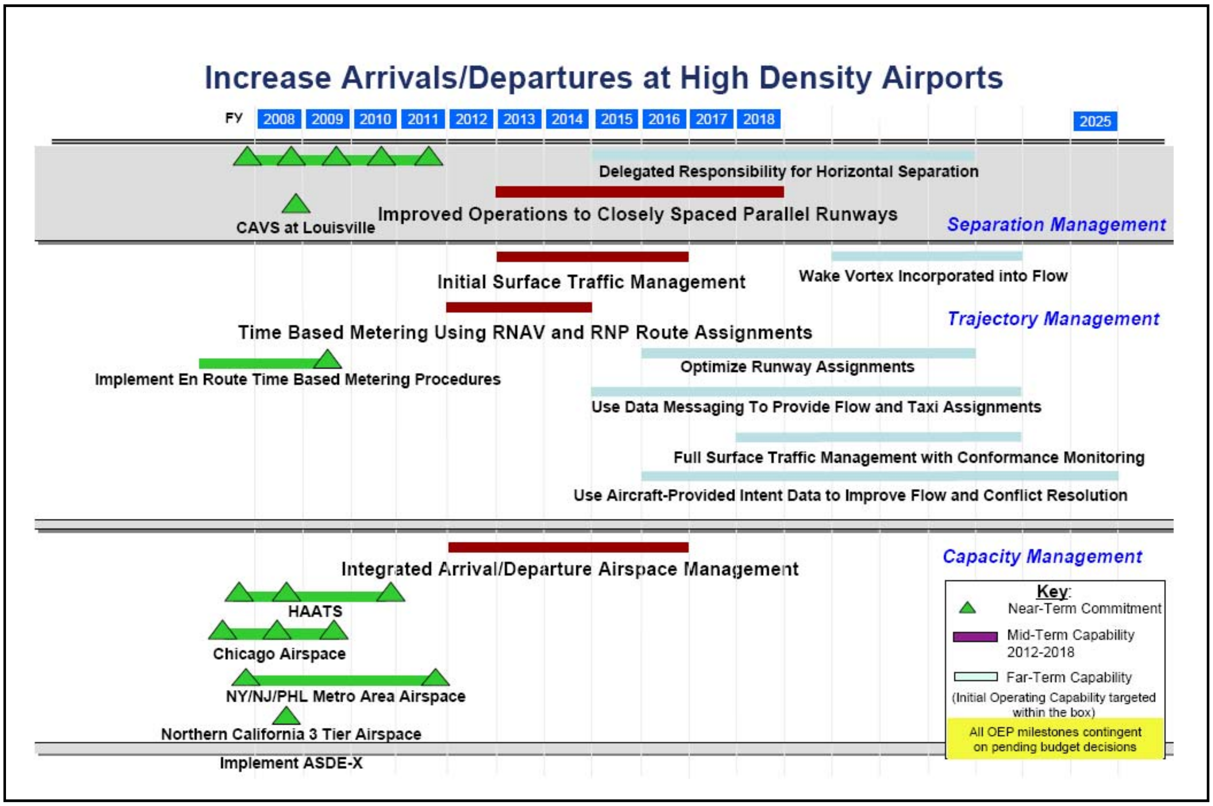
"The Increase Arrivals/Departures at High-Density Airports solution set involves airports (and the airspaces that access those airports) in which:

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

The above defined airports require all the capabilities of the flexible terminals and airspace plus integrated tactical and strategic flow capabilities. They may require higher performance navigation and communications capabilities for ANS providers and the aircraft to support these additional operational requirements." [Increase Arrivals/ Departures at High-Density Airports Solution Set Smart Sheet, 2008]

The OIs of interest for this white paper are listed here and appear in the Increase Arrivals/ Departures at High-Density Airports roadmap figure below:

- Integrated Arrival/Departure Airspace Management
- Time-Based Metering Using RNAV and RNP Route Assignments
- Improved Operations to Closely Spaced Parallel Runways
- Initial Surface Traffic Management



A-2.1.3 Definitions

This section defines key processes and terms used in this paper.

<u>Processes</u>

- Identification of candidate weather integration into Decision Support Tools (DST) involves linking an aviation decision making process, algorithm, or decision aid with an operational need for weather information, for example:
  - Operational air traffic recommendations such as airport configuration change options are associated with changing weather conditions (e.g., wind shifts),
  - Calculations such as trajectory estimation need to incorporate the impacts of weather on flight performance and speed,
  - Airspace and airport capacity prediction are impacted by both severe and routine weather (e.g., thunderstorms, obstructions to vision, winds), and
  - Visual aids to decision making such as traffic displays require weather information be overlaid to identify constraints to flights and traffic flows.
- Description of candidate weather integration goes on to describe in more detail the role weather plays in these decisions, for example:
  - From historical Aviation System Performance Metrics (ASPM) data, empirical analysis can identify weather-parameter thresholds (e.g., winds) that identify historical runway configuration usage. These thresholds can then be used by DST algorithms to identify and recommend operational runway configurations based on current weather conditions;
  - Integration of weather information into sophisticated trajectory estimation algorithms can be used to recommend a Controlled Time of Arrival (CTA) to a metering fix in support of high density airport operations:

    Detailed "Big Airspace" terminal wind fields (particularly near merge points and the jet stream's edge),

    Temperature and barometric pressure profiles (used to calculate geometric altitude), and

    Icing and turbulence (because of their impact on aircraft performance).

<u>Terms</u>

- **4-Dimensional (4-D) Weather (Wx) Single Authoritative Source (SAS)** is one or more 4-D grid(s) of the 'best' representation of ATM aviation-specific observations, analyses, and forecasts (including probability) and climatology organized by 3-dimensional (3-D) spatial and time components (x, y, z, t) that supports NextGen ATM aviation decision making.

- **4-D Wx Data Cube** is a 4-D grid of aviation-specific weather observations, analyses, and forecasts organized by 3-D spatial and time components (x, y, z, and t). The data in the cube is used to develop the 4-D Wx SAS that supports NextGen air traffic management decision making. The 4-D Wx Data Cube is the distributed collection of all relevant aviation weather information formed from the merger of observations, automated gridded products, models, climatological data, and human forecasters input from both public and private sources. The production of the 4-D Wx Data Cube, and its utilization by National Airspace System (NAS) users' applications in an integrated, operational manner, is the essence of NextGen weather capabilities.

A-2.1.4 Methodology

In order for the JPDO to identify and describe potential candidates for mid-term weather integration into DSTs, it is essential that the corresponding OIs are first clearly and thoroughly understood. Therefore, the first step in ATM-weather integration planning is to study the descriptions of the four Increase Arrivals/Departures at High Density Airports mid-term OIs listed in Section A-2.1.2. Our examination found these descriptions did not provide sufficient detail to support our purpose. Additionally, we found instances in which the descriptions were somewhat ambiguous and/or confusing. A subsequent review of a broad range of NextGen documentation added little to our knowledge of these four OIs. It should be noted that later this year the JPDO ANS WG may draft white papers for their mid-term OIs in the Trajectory Based Operations (TBO), Increase Arrivals/Departures at High Density Airports, Flexible Terminal, and Collaborative-ATM (C-ATM) solution sets. This would probably provide the JPDO ATM-weather integration team with the correct level of understanding of the Increase Arrivals/ Departures at High Density Airport mid-term OIs, but it would come too late to meet our work schedule (i.e., v1.0 by September 30, 2009). Having discovered the information we require to perform our task did not yet exist, we set out to expand upon our understanding of the existing OI descriptions through discussions with high density airport Subject Matter Experts (SME). Our first step was to form a discussion group of these SME to clarify and extend our understanding of the Increase Arrivals/Departures at High Density Airport mid-term OIs. This group included: key JPDO ANS and Weather WG members, JPDO ATM Weather Integration Plan writing staff, the coordinator of the Increase Arrivals/Departures at High-Density Airports solution set, ATO-T (both headquarters and operations), and MITRE staff developing scenarios for the FAA I&I team. Over several months, we discussed each of the four mid-term Increase Arrivals/Departures at High Density Airports OIs to enhance the OI descriptions to a point where weather-related decisions became more obvious, and we could proceed to identify and describe weather integration candidates.

A-2.1.5 Outline

SectionsA-2. 2 through A-2.5 apply this methodology to each of the four mid-term OIs listed above for the Increase Arrivals/Departures at High-Density Airports solution set. These sections document OI goals, needs/shortfalls, descriptions, and design/architecture; develop assumptions as to what these OIs really intend; identify and describe 'potential' candidates for weather integration; develop scenarios; and identify weather needs. Section 6 provides weather integration findings, conclusions and recommendations across the Increase Arrivals/Departures at High Density Airport solution set.

A-2.2 Integrated Arrival/Departure Airspace Management (OI-0307, OI-104122)

A-2.2.1 Major Mid-term Goals

Support optimal terminal area configuration management by tailoring capacity to meet demand, managing delay, giving consideration to environmental factors, and better addressing metroplex inter-dependencies.

A-2.2.2 Mid-term Operational Needs/Shortfalls

"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." [Increase Arrivals/ Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.2.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-2.2.3.1 are direct quotes from NextGen documents and those in Section A-2.2.3.2 are clarifications developed via the methodology described in Section 1.4. At this point in time, the clarified capabilities in Section A-2.2.3.2 are only assumptions.

A-2.2.3.1 Documented 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. Air Navigation Service Provider (ANSP) DSTs are instrumental in scheduling and staging arrivals and departures based on airport demand, aircraft capabilities, and gate assignments. This capability expands the use of terminal separation standards and procedures (e.g., 3 nm, degrees divergence, and visual separation) 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 Area Navigation (RNAV) and Required Navigation Performance (RNP) procedures within the transition airspace to allow for increased throughput." [NextGen Integrated Work Plan (IWP) v1.0, 2008]

"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.

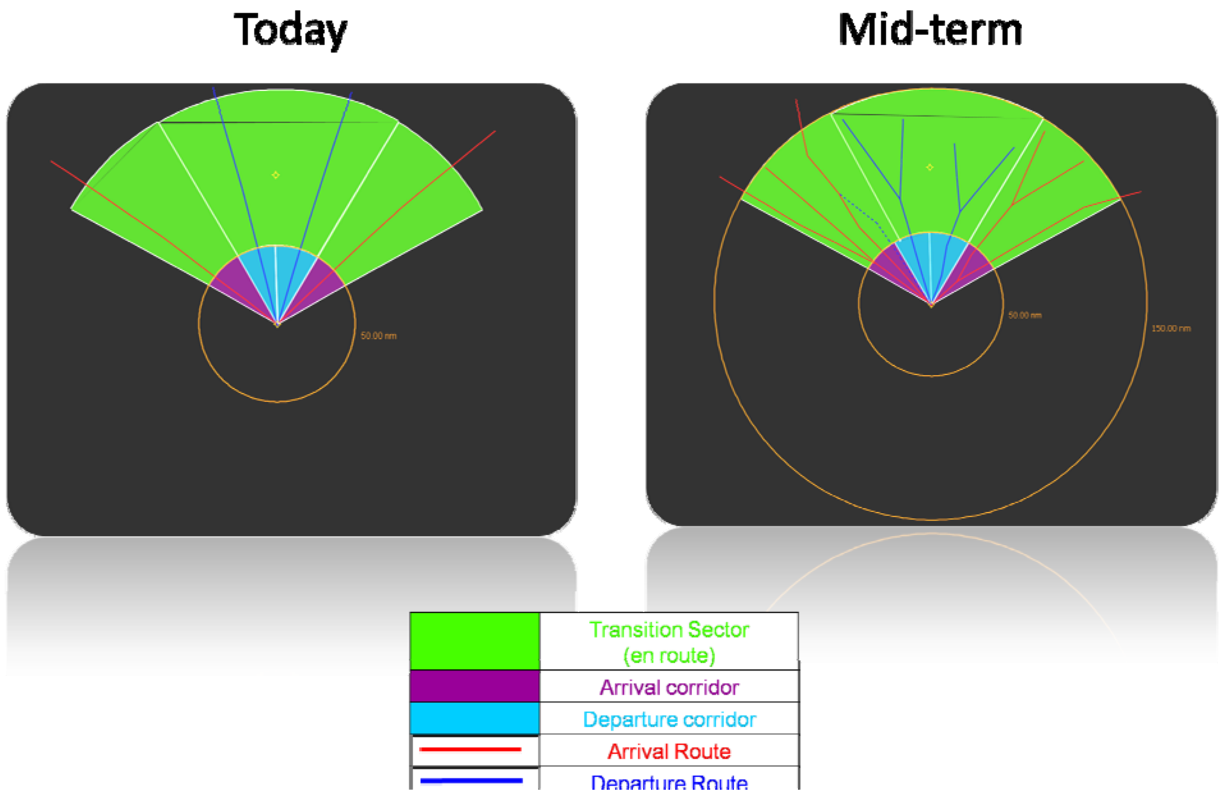
Enhanced traffic management tools will analyze flights approaching an airport from hundreds of miles away, across the facility boundaries that limit the capability today, and will calculate scheduled arrival times to maximize arrival capacity. This will provide controllers with automated information 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 importantly, 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." [NextGen Implementation Plan (NGIP), 2009]

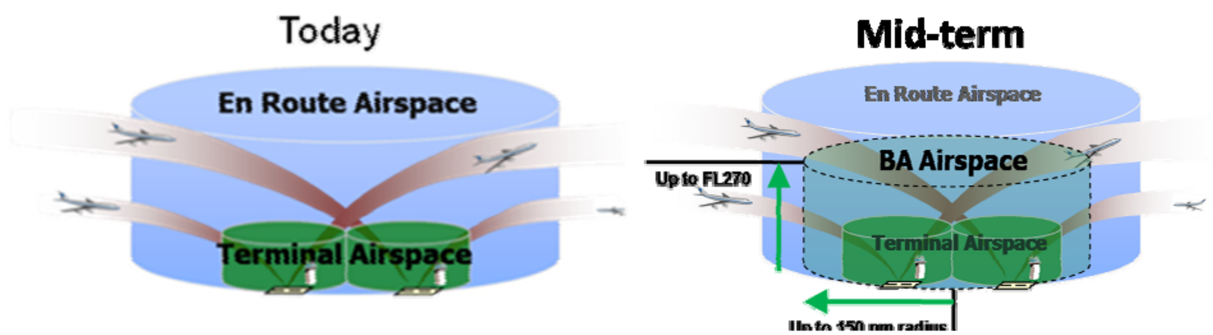
A-2.2.3.2 Capabilities Clarified

Mid-term capabilities for Integrated Arrival/Departure Airspace Management operations may include:

- Increased number and complexity of static arrival and departure configurations supported by Decision Support (DS) automation (see figure below) including:
  - More diverse configurations
  - RNP routes closer to one another allowing additional static arrival and departure routes
  - More complex merging
  - Bi-directional routes (180 degree switching of routes between configurations)
- More timely arrival/departure configuration changes, using weather information to better predict the timing of such changes



- Extension, further into today's en route airspace, 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. The Figure below depicts this Big Airspace (BA) concept.
  - The 3 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 DS automation 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 Automatic Dependent Surveillance – Broadcast mode [ADS-B] signals), including Cockpit Display of Traffic Information (CDTI) Assisted Visual Separation (CAVS) that enable aircraft briefly passing through a thin cloud layer to maintain visual separation augmented by CDTI



A-2.2.4 Mid-term Design/Architecture

"The integrated arrival/departure airspace structure and supporting infrastructure is primarily applicable to high-density, complex metropolitan areas. RNAV-equipped aircraft and trained crew and controllers (on new RNAV procedures) are essential. In order to take full advantage of these capabilities and to increase flexibility over time, terminal separation procedures are linked to a required surveillance performance for the positional information, rather than an equipment-specific requirement. Key enabling programs include:

- En Route Automation Modernization (ERAM) Release 3 (2011-2012) and
- Traffic Management Advisor (TMA) Upgrades (2008-2011)."

[Increase Arrivals/ Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.2.5 Mid-term Candidate Weather Integration

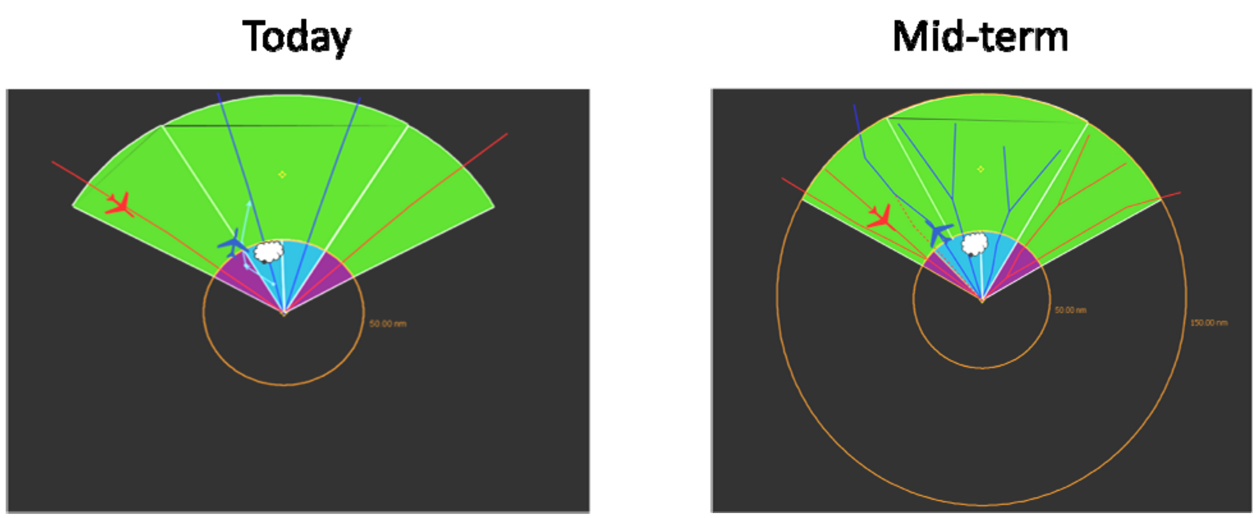
Integrated Arrival/Departure Airspace Management retrieves/subscribes to updates of weather information to support planning/re-planning. In particular, the 4-D Wx Data Cube and the 4-D Wx SAS support enhanced volumetric extractions, by time frame of interest, of weather information to quickly filter the enhanced weather content to the region of interest for impact analysis. Subscriptions provide weather information 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 2 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 terminal area 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, ceiling and visibility) 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).

The figures below represent 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). The figure below and to the left 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). The figure below and to the right 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).



A-2.2.6 Linkage to Near- and Far-term

The mid-term OI, Integrated Arrival/Departure Airspace Management, is a first step towards a full NextGen capability. Table A-2.2.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-2.2.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-2.2.8 to assist us in identifying mid-term weather needs.

Table A-2.2.6 Integrated Arrival/Departure Airspace Management – Linkage to Near- and Far-term

<u>Near –Term</u>

a) There is no common weather picture available to all users, weather information is gathered from multiple sources and individual ANSP perceptions are used to determine the "best source".
b) The number and complexity of static arrival/departure configuration options is limited.
c) Configuring the airport is reactive and the selection of an optimal configuration is a manual process, with weather impact cognitively determined.
d) ANSPs have little DS capability to assist in airport configuration changes.

<u>Mid-Term (Transition to NextGen)</u>

a) Weather common situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS).
b) Terminal airspace designers use climatological studies to generate additional, more complex, static arrival/departure configurations.
c) DS supports/recommends an optimal day of flight arrival/departure configuration plus one or 2 alternates, based on a rules based examination of traffic density, 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. Then, the Traffic Management Coordinator (TMC), collaborating with the facility supervisor, selects an arrival/departure configuration. This capability is closely coordinated with *Initial Surface Traffic Management*, which is responsible for establishing the baseline airport configuration for the day of flight.
d) DS supports/recommends when major changes to the arrival/departure configuration may be needed (e.g., after an examination of wind shift timing information) and proceeds to make recommendations as described in item c above. This capability is closely coordinated with *Initial Surface Traffic Management*, which is responsible for airport configuration changes.
e) DS supports/recommends a modified arrival/departure configuration plus one or 2 alternates to avoid hazardous weather, based on a rules based examination of traffic density, 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, ceiling/visibility, as well as rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorms on arrival/departure routes). Then, the TMC, collaborating with the facility supervisor, selects a modified arrival/departure configuration.
f) *Integrated Arrival/Departure Airspace Management* needs to be integrated with

Initial Surface Traffic Management to coordinate airport and arrival/departure configurations.

Far-Term (Full NextGen)

a) The mid-term's *Integrated Arrival/Departure Airspace Management* is the first of three steps leading to the full NextGen arrival/departure airspace management capability; the two remaining steps, which involve integration with other OIs, are listed below:

   Integration with Other Capabilities
   a. OI-0331: *Integrated Arrival/Departure and Surface Operations*
   b. OI-0339: *Integrated Arrival/Departure and Surface Traffic Management for Metroplex*

b) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced.

c) Weather OIs also evolve in the far-term to include:
   a. OI-103119a: *Full (2016-2025) Initial Integration of Weather Information into NAS Automation and Decision Making*
   b. OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-2.2.7 Mid-term Operational Scenarios

This section contains the following three scenarios:

- Baseline (strategic) arrival/departure configuration plan for the flight day, using weather forecasts
- Proactive change in arrival/departure configuration due to forecasted wind shift, and
- Reactive arrival/departure configuration changes due to pop-up weather.

A-2.2.7.1 Baseline (strategic) Arrival/Departure Configuration Plan for the Flight Day, Using Weather Forecasts

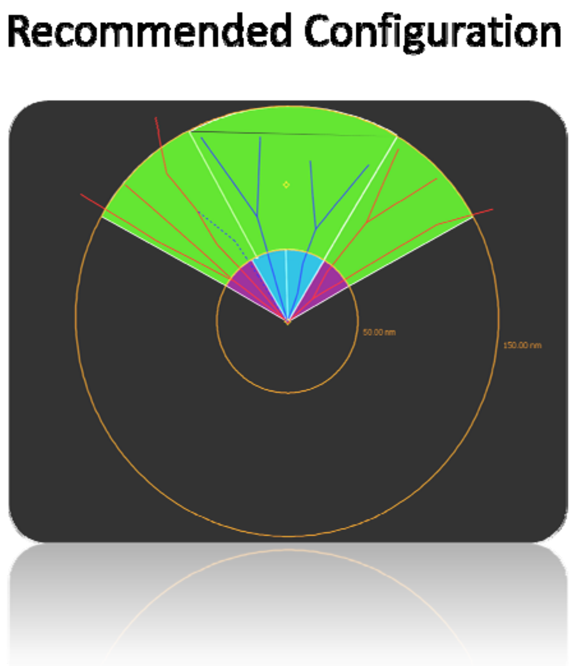
Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DS subscribes to the weather information needed to plan the arrival/departure configuration for the flight day. DS also obtains information concerning traffic density, the performance capabilities of associated 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: DS assists with the development of or recommends an optimal arrival/departure configuration, plus one or 2 alternates, from among the increased number and complexity of predefined arrival/departure configurations. DS 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 DS 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.



A-2.2.7.2 Proactive Change in Arrival/Departure Configuration Due to Forecasted Wind Shift

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DS 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 to a wind shift predicted to occur at the airport in 15 minutes.

Step 1: DS 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), DS assists with the development of or recommends an optimal arrival/departure configuration with 2 or more alternates. In addition to an arrival/departure configuration change, DS assists with the development of or recommends 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 DS 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.

A-2.2.7.3 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. DS subscribes to the weather information needed to identify and plan for dynamic changes to arrival/departure configurations. DS also obtains information concerning traffic density, the performance capabilities of associated aircraft types, as well as environmental considerations in effect.

Step 1: DS, responding to rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorm blocking a departure route), assists with the development of or recommends a minor arrival/departure configuration change, plus one or 2 alternates, to deal with a temporary blockage of a departure route. DS bases this recommendation on an analysis of traffic density, 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, 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 DS recommending that an arrival route be closed and opened as a departure route (see example in figure below). 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 DS 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.

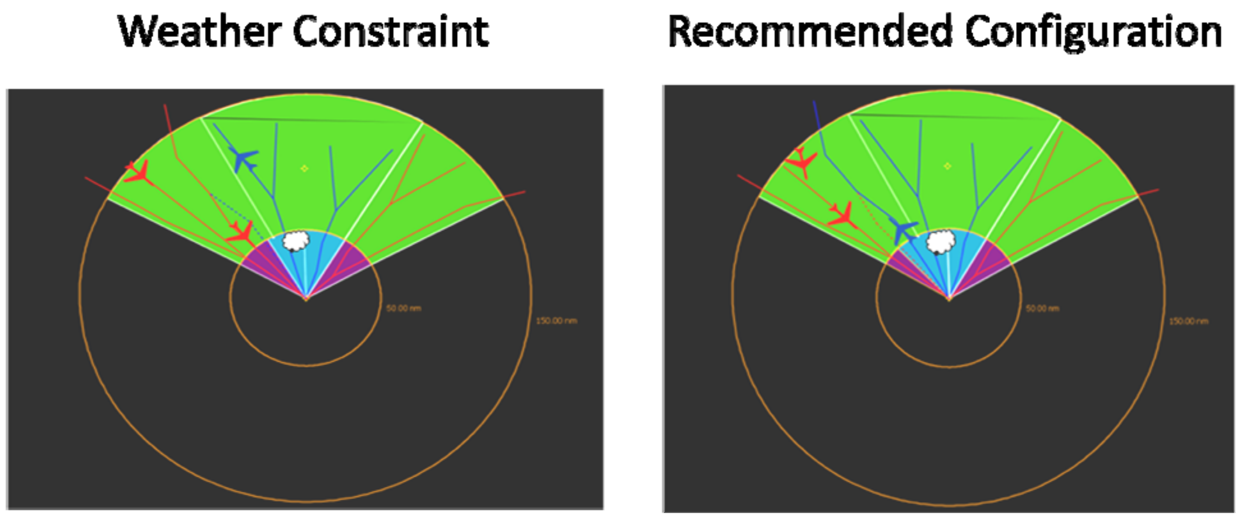
Step 4: The ANSP identifies which upstream arrival aircraft will be last to use the arrival route before it is deactivated and which aircraft is first to be routed to the alternate Standard Terminal Arrival (STAR).

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: The terminal facility coordinates flight plan amendments of flights outside terminal airspace with upstream facility. Traffic Flow Management (TFM) provides amended flight plans to appropriate entities (e.g., affected users or Tower).

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.



A-2.2.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-2.2.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-2.2.8 Integrated Arrival/Departure Airspace Management – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Cube Capability	Mid-Term Wx Information Gap	Recommendations
Support/recommend a stable, baseline	Forecasts out ~8 hrs: • Terminal area winds	<u>Terminal Area Winds</u> • Integrated	TBD	TBD

arrival/departure configuration plan for flight day	(defined by a cone with a radius of 150 nm about the airport, with height up to FL270) • Convection • Ceiling/visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	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) Convection • Corridor Integrated Weather System (CIWS) (0-2 hr) • Consolidated Storm Prediction for Aviation (CoSPA) (2-8 hr) Ceiling/Visibility • Terminal Area Forecast (TAF) • Significant Meteorological Information (SIGMET)		

		• Airman's Meteorological Information (AIRMET) • Graphical 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: • Wind shift timing • Terminal area winds (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) • Convection • Ceiling/visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	Wind shift timing • Derivable from ITWS Terminal Winds Diagnostic Terminal area 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) Convection • CIWS (0-2 hr) Ceiling/Visibility • Meteorological Aviation Report (METAR) • TAF	TBD	TBD

		• SIGMET • AIRMET • G-AIRMET		
Reactively support/recommend arrival/departure configuration modifications in response to rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorms on arrival/departure routes)	Convective weather 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*	Convection • CIWS (0-2 hr)	TBD	TBD

A-2.3 Time-Based Metering Using RNP and RNAV Route Assignments (OI-0325, OI-104123)

A-2.3.1 Major Mid-term Goals

Metering orderly flows of aircraft 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 fixes, which set up streams of aircraft, sequenced and appropriately spaced to efficiently conduct airborne merging and spacing, optimal profile descents, parallel runway operations, wake-based spacing, etc. Departure routing is improved by increasing the accuracy of predicted trajectories.

A-2.3.2 Mid-term Operational Needs/Shortfalls

"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." [Increase Arrivals/ Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.3.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-2.3.3.1 are direct quotes from NextGen documents and those in Section A-2.3.3.2 are clarifications developed via the methodology described in Section A-2.1.4. At this point in time, the clarified capabilities in Section A-2.3.3.2 are only assumptions.

A-2.3.3.1 Documented Capabilities

"RNAV, RNP, and time-based metering 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, time-based metering 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.

C-ATM and time-based metering replace miles in trail 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 Optimized Profile Descent (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 Continuous Descent Arrival (CDA)." [NextGen IWP v1.0, 2008]

A-2.3.3.2 Capabilities Clarified

Time-Based Metering Using RNP and RNAV Route Assignments is assumed to set up an arrival stream by providing a set of CTAs to a metering fix. 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. Time-Based Metering Using RNP and RNAV Route Assignments will also improve departure routing, by increasing the accuracy of predicted trajectories. We are not sure what form of metering is involved with departures, but it should require the same weather information used to calculate CTAs to an arrival metering fix.

A-2.3.4 Mid-term Design/Architecture

"Additional RNAV and RNP routes will be defined that will provide longer and shorter paths. Controller tools will suggest from among the pre-defined RNAV and RNP routes those that efficiently ensure adequate spacing between aircraft. Sites will be selected based on available high levels of equipage to support this operation. Metering will occur in en route airspace in the mid-term. Key Enabling Programs include:

- Traffic Flow Management System Work Package 2 (2011-2016) and
- ERAM Mid-Term Work Package (2013-2017)."

[Increase Arrivals/ Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.3.5 Mid-term Candidate Weather Integration

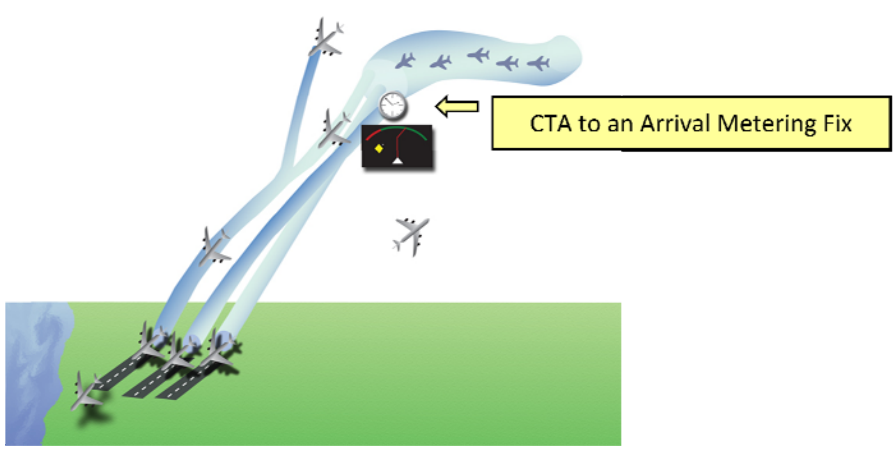
A CTA to an arrival metering fix needs to reflect all aspects of the operations from that metering fix to the runway threshold, including for example pairing for closely spaced runway operations and longitudinal spacing to enable optimal profile descents. The CTA must also reflect what an aircraft can and will actually fly, given the weather conditions along its trajectory. Weather, such as turbulence and icing, impacts aircraft performance including:

- Reduced maximum speed while flying through turbulence and
- Change in idle thrust speed on OPD when icing systems are turned on.

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. An open question is how an area of convective weather between an aircraft and an arrival metering fix will impact Time-Based Metering Using RNP and RNAV Route Assignments CTAs. This more advanced form of weather integration may more appropriately be a far-term capability.

Departure routing is improved by increasing the accuracy of predicted trajectories. As we learn more regarding the scope and nature of this form of metering and its weather integration and information needs, we will update this section. For the present we assume that the weather information needed for this capability is the same that is needed for calculating CTAs to an arrival metering fix.

In order for time-based metering 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 fix.



A-2.3.6 Linkage to Near- and Far-term

The mid-term OI, Time-Based Metering Using RNP and RNAV Route Assignments, is a first step towards a full NextGen capability. Table A-2.3.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-2.3.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-2.3.8 to assist us in identifying mid-term weather needs.

Table A-2.3.6 Time-Based Metering Using RNP and RNAV Route Assignments – Linkage to Near- and Far-term
<u>Near –Term</u> a) There is no common weather picture available to all users, weather information is gathered from multiple sources, and individual ANSP perceptions are used to determine the "best source". b) ANSPs do not currently have DS integrated with weather and aircraft performance information.
<u>Mid-Term (Transition to NextGen)</u> a) Common weather situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS). r) DS integrates weather values directly into algorithms to calculate CTAs to arrival metering fixes, given existing weather conditions, in order to set up streams of traffic to maximize airport capacity, while also supporting user-efficient operations and environmental constraints. s) DS improves departure routing, by increasing the accuracy of predicted trajectories.
<u>Far-Term (Full NextGen)</u> a) This capability will evolve and improve over time, but there are no follow-on OIs planned; improvements will be due to lessons learned, integration with other OIs, and availability of improved weather information. b) Weather OIs also evolve in the far-term to include: c. OI-103119a: *Full (2016-2025) Initial Integration of Weather Information into NAS Automation and Decision Making* • OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-2.3.7 Mid-term Operational Scenarios

This section contains the following scenario:

- Calculate a sequence of recommended CTAs to an arrival metering fix, integrating weather, user preferences, and aircraft performance information
- Improve departure routing, by increasing the accuracy of predicted trajectories

A-2.3.7.1 Calculate a Sequence of Recommended CTAs to an Arrival Metering Fix, Integrating Weather, User Preferences, and Aircraft Performance Information

Step 0: Weather information is made available by the 4-D Wx Data Cube and its initial 4-D Wx SAS. DS subscribes to the weather information needed to calculate lists of CTAs to an arrival metering fix. Users (Airline Operations Center [AOC], Flight Operations

Center [FOC], or pilot) have a time window in which they can input their preferred arrival profile information and/or CTA preferences.

Step 1: DS supports/recommends a sequence of CTAs. The DS recommendation is based on aircraft performance and weather information that may impact the flight trajectory of the aircraft. The weather information includes: detailed wind fields (particularly near merge points), additional wind information near jet stream (if present), temperature and barometric pressure profiles used to calculate geometric altitude, dew point for kinematic modeling, and icing and turbulence because of their impact on aircraft performance. DS integrates this information into trajectory estimation to set up an efficient flow of aircraft.

Step 2: The ANSP may access a 'what if' capability to explore other options or the ANSP can accept the DS recommendations.

Step 3: The ANSP uses the CTA information to manage the aircraft arriving at the fix, either through providing the CTA to the pilot, who is then responsible for meeting it, or through issuing speed changes to non-RTA capable aircraft.

A-2.3.7.2 Improve Departure Routing, by Increasing the Accuracy of Predicted Trajectories

Step 0: TBD

Step 1: TBD

A-2.3.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-2.3.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather 'products', rather it will identify the characteristics of the weather 'information' available in the mid-term.

Table A-2.3.8 Time-Based Metering Using RNP and RNAV Route Assignments – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Cube Capability	Mid-Term Wx Information Gap	Recommendations
t) Calculation of a set of 'attainable' CTAs to an arrival	Forecasts out ~1 hr: • Terminal area winds	<u>Terminal Area Winds</u> • ITWS Terminal	TBD	TBD

metering fix, taking weather's impact on aircraft speed and performance into account	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), with detail particularly near merge points and areas of hard to predict winds near the jet stream's edge • Temperature and barometric pressure profiles to calculate geometric altitude • Dew point for kinematic modeling • In-flight icing and turbulence because of their impact on aircraft performance (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	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 <u>Terminal Area Temperatures</u> • 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 Rapid Refresh Barometric Pressure • RUC In-flight Icing • Current Icing Products (CIP) & 1-9hr Forecast Icing Products (FIP) (Severity, probability, super-cooled large droplets) Turbulence • Analysis and 1-12hr Graphical Turbulence Guidance (GTG)		
u) Improve departure routing, by increasing the accuracy of predicted trajectories	Forecasts out ~1 hr: • Terminal area 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), with detail particularly near merge points and areas of hard to predict	Terminal Area 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-	TBD	TBD

	winds near the jet stream's edge • Temperature and barometric pressure profiles to calculate geometric altitude • Dew point for kinematic modeling • In-flight icing and turbulence because of their impact on aircraft performance (defined by a cone with a radius of 150 nm about the airport, with height up to FL270) *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	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 <u>Terminal Area Temperatures</u> • 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 Rapid Refresh <u>Barometric Pressure</u> • RUC <u>In-flight Icing</u> • CIP & 1-9hr FIP		

		(Severity, probability, super-cooled large droplets) Turbulence Analysis and 1-12hr GTG		

A-2.4 Improve Operations to Closely Spaced Parallel Runways (OI-0333, OI-102141)

A-2.4.1 Major Mid-term Goals

This capability enables continued operations at parallel runways without reduction in throughput in lower visibility conditions.

A-2.4.2 Mid-term Operational Needs/Shortfalls

"Currently, dependent (staggered) operations are allowed in Instrument Meteorological Conditions (IMC) on parallel runways between 2500 feet and 4300 feet. Improved throughput is needed during ceiling and visibility conditions that are less than Visual Meteorological Conditions (VMC) on these runways, as well as those more closely spaced than 2500 feet. Establishing criteria for closely-spaced runways will allow airports to include new runway construction plans compatible with long-term NextGen operations." [Increase Arrivals/ Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.4.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-2.4.3.1 are direct quotes from NextGen documents and those in Section A-2.4.3.2 are clarifications developed via the methodology described in Section A-2.1.4. At this point in time, the clarified capabilities in Section A-2.4.3.2 are only assumptions.

A-2.4.3.1 Documented Capabilities

"This OI involves enhanced procedures (cockpit and ground) enabling parallel runway improvements, reducing impact to airport/runway throughput in lower visibility conditions. It maintains access to closely-spaced parallel runways in limited visibility conditions by integrating new aircraft technologies that will ensure safety through

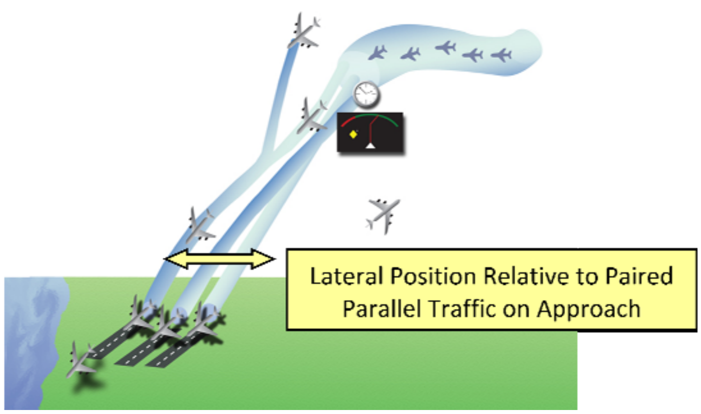
- Precision navigation,
- Aircraft-based monitoring of the aircraft on the parallel approach, and
- Flight guidance to avoid wake vortex generated by parallel traffic.

This capability will apply aircraft-based technologies to maintain closely spaced parallel runway access in IMC, as well as support a new Instrument Flight Rules (IFR) standard for runway spacing.

This OI seeks VMC arrival and departure rates in IMC through use of onboard displays and alerting for independent parallel runways. Using precision navigation, cooperative surveillance, and onboard algorithms and displays allows the reduction of lateral separation requirements for parallel runway operations in IMC. It also includes independent approaches to parallel runways that are centerline distances greater than 2500 ft.” [NextGen IWP v1.0, 2008]

A-2.4.3.2 Capabilities Clarified

It is assumed this capability addresses lateral position relative to paired parallel traffic, whereas Flexible Terminal wake vortex related capabilities address longitudinal separation. Additionally, it is assumed that this OI encompasses all IFR parallel runway operations, ranging from a lateral runway separation of 4300 feet down to as little as 750 feet or possibly even less. This distance is a contradiction to the OI’s title, which infers only closely spaced parallel runways are being considered, although the IWP OI description in the preceding section states independent approaches to parallel runways with centerline distances greater than 2500 feet are also included. 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 (OI-0325) or airborne merging and spacing (OI-0326); current thinking is that both types of operations will be supported and may even peacefully co-exist within a single arrival stream.



A-2.4.4 Mid-term Design/Architecture

“To achieve closely-spaced parallel approaches, it is assumed responsibility for separation between aircraft would be delegated to the aircraft, minimizing the latency of any corrective actions. Aircraft may need assistance during initiation of a paired-approach to ensure they maintain an acceptable along-track tolerance. This maintenance will support other runway procedures (as close as 700 feet) in IMC conditions. Key Enabling Programs include:

- ADS-B.”

[Increase Arrivals/Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.4.5 Mid-term Candidate Weather Integration

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

- Operating under IFR or Visual Flight Rules (VFR) conditions and
- Using parallel offset procedures.

Weather thresholds are established for these determinations. However, there are probably no mid-term needs for integrating weather into DS 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 dependant 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 Global Positioning System (GPS). These 'potential' weather information needs will be examined further and this document will be updated accordingly.

A-2.4.6 Linkage to Near- and Far-term

The mid-term OI, Improve Operations to Closely Spaced Parallel Runways, is a first step towards a full NextGen capability. Table A-2.4.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section A-2. 4.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section A-2.4.8 to assist us in identifying mid-term weather needs.

Table A-2.4.6 Improve Operations to Closely Spaced Parallel Runways – Linkage to Near- and Far-term
Near –Term a) There is no common weather picture available to all users, weather information is gathered from multiple sources (e.g., METAR), and individual ANSP perceptions are used to determine the "best source". b) In the near term, determining whether a set of runways should be operating under IFR or VFR conditions, running dependent or independent operations, and using parallel offset procedures is based on established rules for that runway pair involving values of ceiling and visibility.
Mid-Term (Transition to NextGen) a) Common weather situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS) b) The TMC looks at the ceiling and visibility display and determines the operations in effect based on established rules for that runway pair. The determination of independent vs. dependent (paired) operations is based on the lateral separation between runways. c) The pilot is informed whether operations are IFR or VFR, if runway operations are dependent or independent, and whether parallel runway offset procedures are in effect. d) The pilot maintains the required lateral position relative to paired parallel traffic, specified by the type of operations.

<u>Far-Term (Full NextGen)</u>

a) This capability will evolve and improve over time, but there are no follow-on OIs planned; improvements may include more advanced techniques and procedures for handling runway blunders, triples, and quads.

b) Weather OIs also evolve in the far-term to include:

   d. OI-103119a: *Full (2016-2025) Initial Integration of Weather Information into NAS Automation and Decision Making*

   a. OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-2.4.7 Mid-term Operational Scenarios

This section contains the following scenario:

- Determine runway operations, given existing weather conditions

A-2.4.7.1 Determine Runway Operations, Given Existing Weather Conditions

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 ceiling and visibility conditions to determine: whether parallel runway offset procedures can be used and whether the airport is operating under IFR or VFR conditions. Possibly, TMC looks at cross winds and turbulence conditions paired with lateral runway separation to determine dependant 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.

Step 3: The pilot maintains the required lateral position relative to paired parallel traffic, specified for the type of operation.

A-2.4.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-2.4.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather ‘products’, rather it will identify the characteristics of the weather ‘information’ available in the mid-term

Table A-2.4.8 Improve Operations to Closely Spaced Parallel Runways – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Cube Capability	Mid-Term Wx Information Gap	Recommendations
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: • Ceiling/visibility	Ceiling/Visibility • METAR • TAF • SIGMET • AIRMET • G-AIRMET	TBD	TBD

A-2.5 Initial Surface Traffic Management (OI-0320, OI-104209)

A-2.5.1 Major Mid-term Goals

This capability provides improved sequencing and staging of surface traffic flow at high density airports with consideration for en route weather constraints and availability of routes, enhanced local collaboration between ANSP and airport stakeholders, and an increased opportunity for aircraft operators to meet their operational and business objectives. This capability is also responsible for airport configuration.

A-2.5.2 Mid-term Operational Needs/Shortfalls

"Currently, air traffic demand exceeds inadequate NAS resources. Traffic-flow managers apply a variety of tools, particularly various types of traffic management initiatives (TMIs), to handle departure runways at high-density airports. These initiatives depend upon the capability of 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 decision-support tools to assist controllers in accomplishing this daunting task. Appropriate surface data, when developed, will be shared with flight planners, FOCs, as well as airport authorities." [Increase Arrivals/Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.5.3 Mid-term Planned Capabilities

The mid-term capabilities described in Section A-2.5.3.1 are direct quotes from NextGen documents and those in Section A-2.5.3.2 are clarifications developed via the methodology described in Section A-2.1.4. At this point in time, the clarified capabilities in A-2.5.3.2 are only assumptions.

A-2.5.3.1 Documented Capabilities

"Departures are sequenced and staged to maintain throughput. ANSP automation uses departure-scheduling tools to flow surface traffic at high-density airports. Automation provides surface sequencing and staging lists for departures and average departure delay (current and predicted). ANSP DSTs integrate surveillance data to include weather data, departure queues, aircraft flight plan information, runway configuration, expected departure times, and gate assignments. Automation provides surface sequencing and staging lists for departures and average departure delay (current and predicted). Local collaboration between ANSP and airport stakeholders improves information flow to DS as well as the ability for aircraft operators to meet their operational and business objectives." [NextGen IWP v1.0, 2008]

A-2.5.3.2 Capabilities Clarified

Initial Surface Traffic Management is automated and includes a capability to facilitate looking out into en route flow acceptance rates to determine a more effective flow for high-density airport departures to better sequence, stage, and flow surface traffic. This initial mid-term departure-scheduling tool provides runway assignment, 2-dimensional (2-D) taxi routes, departure routing, surface sequencing and scheduling, as well as average departure delays (current and predicted). To accomplish this, the following information is integrated into the decision making process:

- Weather information,
- Aircraft flight plans,
- Runway configuration,
- Expected departure times, and
- Departure Gate.

Additionally, this capability supports/recommends airport configuration changes and works closely with the Integrated Arrival/Departure Airspace Management's arrival/departure configuration capability. Lastly, this capability provides surface management information in support of a determination of airport capacity. Future versions of this paper will explore this information sharing capability and any related weather integration needs it may have.

In the far-term, follow-on surface traffic management OIs will introduce 'new' or more sophisticated NextGen capabilities, building on this mid-term capability.

According to the ATO-P draft ConUse for Surface Trajectory Based Operations (STBO) Segments 1&2, v0.1, dated 12 December 2008 this surface TBO DST functionality includes:

- Planning and scheduling use of airport resources (e.g., runways and taxiways) to meet user demand, current airport operations, and traffic flow management restrictions, including time-based metering
- More planning and predictability for airport surface traffic management and better coordination among airport stakeholders
- Flight planning may be 2-24 hours before the flight departs and can include early intent flight plans

- Seamless integration and compatibility with other capabilities and operations in conventional towers and Traffic Management in all facilities
- Managing queues for departing flights, at busy airports during peak demand, taking arrivals into account; efficiently using capacity, and providing the mechanism for ATC-flight operator collaboration on departure decisions
- Improving the scheduling of airport surface resources without overly constraining operators
- No change to operational responsibilities; the responsibilities of Air Traffic Control Tower, Traffic Management, Ramp Control, flight operators, and pilots remain the same
- Taking weather (e.g., wind, visibility/ceiling, thunderstorms) into account
- Implementation through the execution of TMIs
- No requirement for new flight deck technologies

A-2.5.4 Mid-term Design/Architecture

"The surface traffic management tool suite will receive data from and provide data to automation systems using Application Programming Interfaces (APIs) and services provided by those systems. Information must be shared with the appropriate systems, such as Traffic Flow Management System (TFMS) infrastructure and ERAM. Appropriate surface management tools may be distributed as needed to support required response times. Key Enabling Programs include:

- Tower Flight Manager (2015+)."

[Increase Arrivals/Departures at High-Density Airports Solution Set Smart Sheet, 2008]

A-2.5.5 Mid-term Candidate Weather Integration

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

- Supports/recommends runway assignment, 2-D taxi routes, departure scheduling, 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 and en route, including terminal area winds, winds aloft, convection, ceiling/visibility, as well as rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorms on arrival/departure routes). For surface sequencing and staging lists, taxi speed will be affected by visibility and environmental factors impacting surface conditions.
- Supports/recommends airport configuration changes, working closely with Integrated Arrival/Departure Airspace Management's arrival/departure configuration capability.

- Provides surface management information supporting the determination of airport capacity. Potential weather integration candidates for this capability are still being considered.

A-2.5.6 Linkage to Near- and Far-term

The mid-term OI, Initial Surface Traffic Management, is a first step towards a full NextGen capability. Table 5.6 describes this initial step, links it back to today's capabilities and commitments, and describes its future evolution. Section 5.7 then develops scenarios, based on this mid-term capability, which are subsequently used in Section 5.8 to assist us in identifying mid-term weather needs.

Table A-2.5.6 *Initial Surface Traffic Management* – Linkage to Near- and Far-term

Near –Term

a) There is no common weather picture available to all users, weather information is gathered from multiple sources, and individual ANSP perceptions are used to determine the "best source".
b) ANSPs do not have DSTs to aid them in sequencing and staging surface traffic flow and in determining current and future average departure delay.

Mid-Term (Transition to NextGen)

a) Common weather situational awareness is available to all aviation stakeholders and automation capabilities (i.e., 4-D Wx SAS).
b) DS supports/recommends an optimal day of flight airport configuration.
c) DS proactively supports/recommends 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.
d) DS departure scheduling tools plug weather values directly into equations to produce surface sequencing and staging lists and to determine average departure delays (current and predicted).
e) *Initial Surface Traffic Management* needs to be integrated with *Integrated Arrival/Departure Airspace Management* to coordinate airport and arrival/departure configurations.

Far-Term (Full NextGen)

a) *Initial Surface Traffic Management* is the first of eight steps leading to the full NextGen surface traffic management capability; the remaining seven steps are:

Additional Surface Traffic Management Capabilities

- OI-0321: *Enhanced Surface Traffic Operations*
- OI-0332: *Ground-Based and On-Board Runway Incursion Alerting*
- OI-0322: *Low-Visibility Surface Operations*
- OI-0327: *Surface Management - Arrivals/Winter Ops/Runway Configuration*
- OI-0340: *Near-Zero-Visibility Surface Operations*

<u>*Integration with Other Capabilities*</u>

- OI-0331: *Integrated Arrival/Departure and Surface Operations*
- OI-0339: *Integrated Arrival/Departure and Surface Traffic Management for Metroplex*

b) By breaking this complex implementation into more manageable steps, benefits are realized sooner and implementation risks are reduced.

c) Weather OIs also evolve in the far-term to include:

- OI-103119a: *Full (2016-2025) Initial Integration of Weather Information into NAS Automation and Decision Making*
- OI-103121: *Full (2016-2025) Improved Weather Information and Dissemination*

A-2.5.7 Mid-term Operational Scenarios

This section contains the following three scenarios:

- Baseline (strategic) airport configuration plan for the flight day, using weather forecasts
- Proactive change in airport configuration due to forecasted wind shift
- Departure staging of surface traffic flow

A-2.5.7.1 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. DS subscribes to the weather information needed to plan the airport configuration for the flight day.

Step 1: DS assists with the development of or recommends an airport configuration. DS 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 DS 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-2.5.7.2 Proactive Change in Airport Configuration Due to Forecasted Wind Shift

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

Step 1: DS 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), DS assists with the development of or recommends an airport configuration change. DS 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 DS may use other methodologies to make its recommendation.

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.

Step 5: The Terminal Radar Approach Control Facility (TRACON) starts sequencing other aircraft to the new airport and arrival/departure configuration.

A-2.5.7.3 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. DS subscribes to the weather information needed to manage surface traffic.

Step 1: DS 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-2.5.8 Mid-term Weather Needs Analysis

Based on the scenarios developed in the previous section, weather needs are analyzed in Table A-2.5.8. The 1st column identifies the weather integration need (i.e., the operational decision that will be supported by a DST), the 2nd column attempts to identify the functional weather needs of that DST, the 3rd column identifies the weather information that will be available in the mid-term (according to current plans), and the 4th column identifies gaps, and the 5th column provides recommendations.

Work on this table has only just begun. The next immediate steps are to focus on and complete columns 2 and 3, so that columns 4 and 5 can be addressed. Please note that in its final form, column 3 will not reference weather ‘products’, rather it will identify the characteristics of the weather ‘information’ available in the mid-term. Please note that in its final form, column 3 will not reference weather ‘products’, rather it will identify the characteristics of the weather ‘information’ available in the mid-term.

Table A-2.5.8 *Initial Surface Traffic Management* – Mid-term Weather Needs Analysis

Mid-Term Wx Integration Need	Mid-Term Wx Information Need	Mid-Term 4-D Wx Cube Capability	Mid-Term Wx Information Gap	Recommendations
Support/recommend a stable, baseline	Forecasts out ~8 hrs: • Surface winds	<u>Terminal Area Winds</u> • ITWS Terminal	TBD	TBD

airport configuration plan for flight day	• Convection • Ceiling/visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	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 <u>Convection</u> • CIWS (0-2 hr) • CoSPA (2-8 hr) <u>Ceiling/Visibility</u> • TAF • SIGMET • AIRMET • G-AIRMET		
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: • Wind shift timing • Convection • Ceiling/visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	<u>Wind shift timing</u> • Derivable from ITWS Terminal Winds Diagnostic <u>Convection</u> • CIWS (0-2 hr) <u>Ceiling/Visibility</u> • METAR • TAF • SIGMET • AIRMET • G-AIRMET	TBD	TBD

Support/recommend surface sequencing and staging lists and determine (current and predicted) average departure delays	Forecasts out ~2-24 hrs: • Terminal area 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) • Convection • Ceiling/ visibility *Accuracy TBD* *Resolution TBD* *Forecast Update Rate TBD* *Latency TBD*	Terminal Area 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 Convection • CIWS (0-2 hr) Ceiling/Visibility • TAFs • SIGMET • AIRMET • G-AIRMET	TBD	TBD

A-2.6 Findings, Conclusions, and Recommendations

Much analysis and discussion are required before a final set of mid-term weather integration candidates for Increase Arrivals/Departures at High Density Airports can be identified. From among the 'potential' weather integration candidates listed below, some may be incorporated into Increase Arrivals/Departures at High Density Airports ConOps documents, forming the basis for NextGen weather integration requirements.

A-2.6.1 Findings

To-date, the following mid-term, Increase Arrivals/Departures at High Density Airports, weather-related, operational decisions have been identified as 'potential' candidates for inclusion into DSTs.

Integrated Arrival/Departure Airspace Management

- Support/recommend a stable, baseline arrival/departure configuration plan for the flight day
- Proactively support/recommend arrival/departure configuration modifications, far enough in advance of predicted weather (e.g., wind shift), to efficiently move traffic to new arrival/departure configurations
- Reactively support/recommend arrival/departure configuration modifications in response to rapidly changing and highly localized weather conditions (e.g., pop-up thunderstorms on arrival/departure routes)

Time-Based Metering Using RNP and RNAV Route Assignments

- Calculation of a set of 'attainable' CTAs to an arrival metering fix, taking weather's impact on aircraft speed and performance into account
- Improve Departure Routing, by Increasing the Accuracy of Predicted Trajectories

Initial Surface Traffic Management

- Support/recommend a stable, baseline airport configuration plan for the flight day
- 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 surface sequencing and staging lists and determine (current and predicted) average departure delays

A-2.6.2 Conclusions

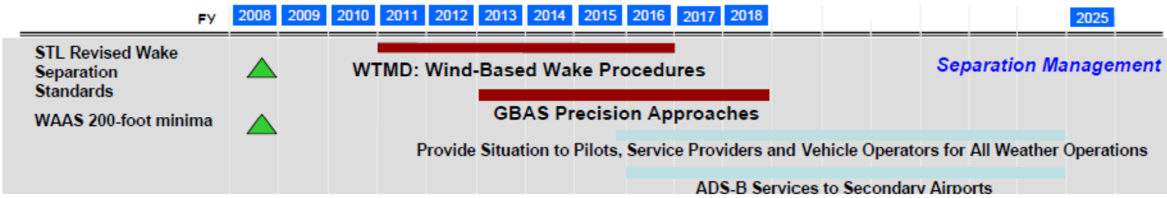
The authors of this document need to perform more analysis and receive more feedback on this initial version, before conclusions can be reached.

A-2.6.3 Recommendations

The authors of this document need to perform more analysis and receive more feedback on this initial version, before recommendations can be made.

A-3. Increase Flexibility in the Terminal Environment

Flexible terminal 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. 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.



A-3.1 Separation Management

<u>Near-term Commitments</u>

<u>STL Revised Wake Separation Standards</u>

This initiative will provide for dependent, staggered operations at St. Louis on closely-spaced parallels based on an understanding of wake transport limits.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

<u>Comments</u>

Prediction of wake transport and decay requires accurate ambient winds and turbulence, even in the near term.

<u>WAAS 200-Foot Minima</u>

This initiative will extend the use of the Wide-Area Augmentation System down to 200 feet above an airport's elevation at runway ends without instrument landing systems in Alaska.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

<u>Mid-term Capabilities</u>

A-3.1.1. Wake Turbulence Mitigation for Departures (WTMD) - Wind-Based Wake Procedures

This operational improvement will leverage improved wake vortex (WV) prediction capabilities, and the integration of that WV information into display systems and decision support tools (DSTs) which identify and mitigate the impact of wake turbulence generated by one aircraft on a following aircraft. As compared to the generalized methodologies employed today, this flight pair-specific approach to dealing with wake turbulence should allow for the reduction of spacing between aircraft, thereby improving runway capacities across a range of weather conditions and operating regimes. Implicit in this statement is that existing wake vortex-based separation rules will be changed based on the capability of WTMD-based systems to predict the transport or decay of wake vortices and their precise impact on the trailing aircraft.

Although this Operational Improvement (OI) specifically focuses on wake mitigation in the departure regime, and is therefore assumed to be concerned primarily with longitudinal separation between departing aircraft, there is also the need for similar capabilities in the arrival regime, and especially for arrivals to Closely Spaced Parallel Runways (CSPRs). It is almost certain that the display systems and DSTs created to provide Wake Turbulence Mitigation for Arrivals (WTMA) will require the same weather inputs as will procedures and DSTs designed to provide WTMD, despite the fact that the resultant arrival processes are likely to be concerned with the lateral, instead of longitudinal, separation of aircraft landing on adjacent runways. See Appendix A-2.3, Improved Operations to Closely Spaced Runways, for additional WTMA discussion in the context of closely spaced parallel runways.

Framework Assumptions (AOC/FOC = Airline/Flight Operations Center, ATC = Air Traffic Control, PIC = Aircraft)

Today / Near-term (current to 2010)

- (ATC) The impact of current weather on wake turbulence is not a factor in the development of arrival/departure rates
- (ATC) The impact of wake turbulence is manually mitigated through the application of miles in trail between departure aircraft following standards based on the application of FAA rules
- (ATC) The impact of wake turbulence on the airport operation is manually computed
- (AOC/FOC, PIC) Neither the dispatcher nor the pilot has any awareness of the real time impact of wake turbulence on the airport operation
- (ATC) The estimation of traffic demand is derived from multiple sources and then manually adjusted based on history and controller experience
- (ATC, PIC) Pilots are allowed to use their judgment of the impact of wake turbulence on their flight during visual approach only in following traffic

Mid-term (2010-2018)

- (ATC) A wake turbulence mitigation model based on actual local weather conditions will be developed and used by local ATC
- (ATC) The impact of wake turbulence on airport arrival/departure rates will continue to be manually derived through human interpretation of the wake turbulence mitigation models and related information
- (ATC) Human interpretation of tower displays will be used to make departure runway assignments and apply departure separation criteria on the basis of wake turbulence
- (PIC) There will be no change in cockpit wake turbulence information or rules
- (AOC/FOC, PIC) The dispatcher and the pilot will continue to be unaware of the real time impact of wake turbulence on the airport operation

Far-term (2018-2025)

- (ATC) Decision support tools (DSTs) which include an integrated wake turbulence mitigation model based on local weather conditions will be used to automatically calculate wake turbulence-based separation criteria and make related operational decisions

- (AOC/FOC, ATC, PIC) These DSTs will provide a visual display of wake turbulence impact zones to AOC/FOC, ATC and aircraft cockpit display systems
- (ATC) These DSTs will automatically adjust airport arrival and departure rates based on the integrated wake turbulence mitigation model and local weather conditions
- (AOC/FOC, ATC, PIC) Dispatchers, controllers and pilots will all see a common view of wake turbulence, and share a common understanding of the impact of wake turbulence on the airport operation
- (AOC/FOC, ATC) When coupled with more accurate and detailed surface forecasts, dispatchers and controllers will share an early and common understanding of the impact of wake turbulence on the capacity of the airport later in the day

<u>Comments</u>

- WTMD weather integration is envisioned to mean that high resolution, real time local wind data and high resolution, high refresh rate wind forecasts are part of a wind forecast algorithm which in turn is integrated into the WTMD processing function
- Prediction of wake transport and decay requires accurate ambient winds and turbulence, even in the near term. Terminal area (and/or airborne - longer term) wake sensor systems are also important to confirm predictions, and for safety.
- ATC policies and procedures will have to be changed to allow differing separation criteria based on information from wake turbulence mitigation models, regardless of whether the separation criteria are calculated and assigned manually or automatically

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

- Enhanced Forecasts - Terminal Winds – must be input to wake vortex (WV) system. More specifically, wake vortex prediction systems are anticipated to create high temporal and spatial wind observation and reporting requirements.

<u>Integrated Work Plan (IWP) Review</u>

- There are two IWP Operational Improvements (OIs) and several underlying Enablers (ENs) that support the envisioned capabilities for Wake Turbulence Mitigation found in the NextGen Implementation Plan (NIP) Flex Terminal Solution Set Separation Management Swim Lane.
- OI-0402 - Wake Turbulence Mitigation: Departures - Dynamic Wind Procedures (2018) has as its focus predicting wake drift and decay. It is envisioned that this will be used to dynamically adjust longitudinal departure spacing and separation rules based on ground-based winds, aircraft type and algorithms. This OI builds on the ability to adjust for lateral wake effects and associated static procedures for Closely Spaced Parallel Runways (CSPR).

- EN-0029 - Wake Detection/Prediction with Dynamic Wake Spacing - Level 1 Wake Drift (2014) is a ground-based wake vortex advisory system based solely on wake transport.
- EN-0030 - Wake Detection/Prediction with Dynamic Wake Spacing - Level 2 Wake Drift/Decay (2016) builds on EN-0029 to include wake decay.

Comment: EN-0029 and EN-0030 describe a ground-based wake vortex advisory system that presumably includes high spatial and temporal wind observations and whose sole focus is on wake vortex detection, prediction and aircraft spacing guidance in the terminal area, and especially for impacts to operations on closely spaced parallel runways (CSPR). It has been estimated in the NextGen Portfolio Work Plan on Resource Planning Data (RPD) that several additional departures per hour from CSPRs are possible, if the dissipation and transport of the wake turbulence can be predicted. Regardless, however, of where or how weather information is integrated, the net effect on improved operations will be driven by changes in separation standards and procedures.

OI-0409 - Net-Centric Virtual Facility (2018) is an overarching OI that supports Flex Terminal as well as other airport-based improvements. This OI has a focus of obtaining situational awareness information remotely. The OI is aided by weather, traffic and other surface surveillance information displayed on a tower information display system and a suite of decision support tools using ground system and aircraft-derived data.

<u>REDAC Review</u>

Nothing noted

<u>Weather/ATM Integration Conference Review</u>

Nothing noted

A-3.1.2 Ground-Based Augmentation System (GBAS) Precision Approaches

Global Positioning System (GPS)/GBAS will 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.

As an integral part of the overall ATM system, it is essential that airports provide and manage surface guidance systems, maximizing the airport capacity, and providing enhanced protection against runway incursions and misrouting, under all weather conditions. Currently surface movement radar is the basic means for ATC surface surveillance. However radar only provides an approximate position of the aircraft and by itself does not provide the required accuracy for surface movement under zero visibility conditions to increase situational awareness and mitigate potential runway incursions. Further, it is envisioned that the current IFR Landing Systems will not be able to meet future capacity and safety needs of CAT III approaches Thus, in order to optimize travel operational capacity, the functionality for surface movement and potential effects from weather should be incorporated into the GBAS architecture for Category-III landings.

The Global Positioning System (GPS)/GBAS will 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.

<u>Framework Assumptions</u> (AOC/FOC = Airline/Flight Operations Center, ATC = Air Traffic Control, PIC = Aircraft)

Today / Near-term (current to 2010)

- (ATC) The instrument landing system (ILS) is the current standard at most major airports, with the equipment and level of ILS (Cat I/II/III) based on level of traffic and the level of weather impact.
- (PIC) Aircraft equipment and pilot training can impact the ILS Cat the flight is able to use.
- (AOC/FOC, PIC) Some aircraft operators equip and train to a cost/benefit level for the normal operations at the airport.
- (ATC) RNAV approaches have been developed at number of airports
- (ATC) RNAV STARS have been developed for a number of airports
- (ATC) Surface radar is installed at most of the major airports for tracking surface operations
- (ATC, PIC) Visual observation on surface operations is still the primary mode used today with pilot position reports as a supplements

Mid-term (2010-2018)

- GBAS is based on the current RNAV equipment and, augmented by Local Area Augmentation System (LAAS), transition should be seamless.
- Current RNAV approach development should lead to rapid transition to GBAS approaches.
- Current satellite systems are being upgraded to block IIF and eventually block III. Note – KS-M suggests that, based on her knowledge of satellite launch schedules, this date will not be met. I have asked her for more information and/or to change the words appropriately. Standing by for feedback.
- Ground based system is currently being tested at Memphis.
- Transition from ground based equipment to satellite based will be cost driven for both the FAA and customers life cycle of equipment and airport needs will be a factor.
- Based on the cost to upgrade aircraft equipment, the development of a program atmospheric impact on system may be needed.

Far-term (2018-2025)

- Continue development as needed.
- New civilian frequency for GPS (L5) will be available by 2015

Weather Integration Considerations – Infrastructure Roadmap (IR)

- Enhanced Forecasts – Forecasts of Space Weather - solar activity can degrade GPS signal

<u>Issues/Risks/Comments</u>

The effects of weather and its integration within GBAS calculations may be driven by functions that perform differential corrections (to improve accuracy), integrity monitoring (to ensure that errors are within tolerable limits with a very high probability and thus ensure safety), and ranging (to improve availability). Additional corrections of the GPS may be necessary due to ionospheric scintillation. However, new GPS receivers and codes are being implemented that will allow ionospheric ranging errors to be removed. In the late mid-term, aircraft based systems including radar and imaging sensors may be used to confirm the aircraft's position by comparing sensor data to databases of terrain and cultural features, confirming and augmenting GPS/GBAS to provide enhanced accuracy and integrity. There may be additional consideration for degraded GBAS signal on the flight deck before ground-based detection. This would infer the need for weather integration into cockpit avionics for this application.

<u>Integrated Work Plan (IWP) Review</u>

The IWP OI which supports the IFTE NIP Swim Lane capabilities for GBAS is OI-0381 GBAS Precision Approaches (2017). It is envisioned that a single GBAS system would provide precision-approach capabilities to multiple runways or landing areas when combined with other technologies such as enhanced lighting systems.

GBAS provides a service that is robust to atmospheric phenomena that might cause loss of Satellite-Based Augmentation Systems (SBAS) vertical guidance. However all radio systems which rely on radio wave communication through the atmosphere are sensitive to the effects of atmospheric disturbances such as those produced by solar storms. Space weather impacts on GNSS include the introduction of range errors and the loss of signal reception. As such, the arrival (begin time), duration, or end time of solar radiation maximums, geomagnetic storm activity, solar flares, coronal mass ejections and other high solar energy, radio blackout or degraded communication frequency events may be needed. The space weather performance and fidelity requirements will need to be determined.

No supporting enablers were identified.

<u>REDAC Review</u>

Nothing noted

<u>Weather/ATM Integration Conference Review</u>

Nothing noted

<u>Far-term Capabilities</u>

Provide Surface Situation to Pilots, Service Providers and Vehicle Operators for All-weather Operations

Aircraft and surface vehicle positions are displayed to air navigation service providers (ANSP) and equipped aircraft and vehicles. This capability increases situational awareness in restricted visibility conditions and provides more efficient surface movement.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

- Weather Information in user specified resolution for integration to DSTs
- Provide Improved Weather Information Distribution

<u>Issues/Risks/Comments</u>

- Weather capability support: Near-real time dissemination of weather information
- To all ground users: High resolution observed visibility

<u>ADS-B Services to Secondary Airports</u>

Expanded Automatic Dependent Surveillance-Broadcast (ADS-B) coverage, combined with other radar sources, provides equipped aircraft with radar-like services to secondary airports. Equipped aircraft automatically receive airborne broadcast traffic information. Surface traffic information is available at select non-towered satellite airports.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

A-3.2 Trajectory Management

<u>Near-term Commitments</u>

<u>Limited Use of Continuous Descent Arrivals at SDF, LAX, ATL</u>

This will extend the use of Continuous Descent Arrivals during very low traffic situations at Louisville, Los Angeles, and Atlanta so that aircraft can perform efficient, low noise and low pollution arrivals.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

<u>Mid-term Capabilities</u>

A-3.2.1 Use Optimized Profile Descent

Optimized Profile Descents (OPDs) (also known as Continuous Descent Arrivals -- 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.

<u>Comments</u>

The integration of high resolution terminal winds into aircraft equipped with onboard energy management guidance systems may allow these aircraft to fly precise 4DTs that are highly optimized for fuel efficiency. Minimally equipped aircraft, in contrast, may fly a more basic OPD that simply applies idle thrust wherever possible. In addition, the precise 4DT flown by an aircraft on an OPD will vary by a number of factors including winds aloft, aircraft weight, and top of descent point.

Although this capability focuses on the need for accurate winds aloft data for OPD operations, pilots and controllers will need more information in order to consistently plan and complete OPDs, such as improved observations and forecasts of winds and hazards to aviation such as convectively induced turbulence (CIT), clear air turbulence (CAT), lightning and hail. Further investigation of these weather factors, any or all of which can impact OPD operations, and how to integrate them into OPD-related decision support tools, needs to be undertaken in order to improve OPD planning and operations.

To that end, existing airborne capabilities of measuring wind, turbulence, temperature, humidity and icing need to be improved and fully leveraged. Processes which enable and encourage the transmission of this information to ground systems and adjacent aircraft must be developed, and then that information must be incorporated into weather forecast models and ATM and onboard decision support tools as appropriate

<u>Framework Assumptions</u> (AOC/FOC = Airline Operations Center, ATC = Air Traffic Control, PIC = Aircraft)

Today / Near-term (current to 2010)

- Current arrival procedures limit OPD to low traffic volume times, late night and mid-night operations.
- Current TRACON Controllers lack DST's to support OPD operations.
- Current weather forecast provides limited use for the detailed preplanning of OPD operations.

Mid-term (2010-2018)

- Develop arrival procedures to enable pilots and equipped aircraft to utilize OPD operations.
- Increase the scale of terminal forecast to provide for OPD planning and operations

- Improved airborne observation capabilities including near real-time wind, turbulence, temperature, humidity and icing will be used to improve OPD planning and operations, along with the 4-D4-D Wx Data Cube and the 4-D Wx SAS

Far-term (2018-2025)

- ADS-B will allow aircraft to aircraft separation and link aircraft to follow each other.

Weather Integration Considerations – Infrastructure Roadmap (IR)

Enhanced Forecast – Terminal Winds

Issues/Risks/Comments

- Model output – Improved Forecast of Winds throughout descents
- 4-D Wx SAS – Improved Forecast Winds throughout descent
- Sensors feeding the 4-D Wx SAS: Wind shear detection (e.g. LLWAS), ASR-WSP, TDWR, LIDAR, ASR-8/9/11, NEXRAD, F-420, DASI, ASOS, AWOS, AWSS, SAWS, NextGen Surface Observing
- NextGen surface observation sensors that are networked and then combined to form a common, de-conflicted weather source

Integrated Work Plan (IWP) Review

The IWP OI which supports the IFTE NIP Swim Lane capabilities for OPD is OI-0329 Airborne Merging and Spacing with OPD (2015). This OI suggests that, together with airborne merging and spacing capability and airborne guidance, optimized OPD is performed while staying within assigned lateral and vertical airspace corridor limits. This results in improved individual aircraft fuel reduction through onboard energy guidance and enables reduced spacing buffers (increased throughput from precision airborne spacing). This OI requires an Implementation Decision to determine appropriate trajectory restrictions laterally, vertically, and in time, based on trade off between aircraft performance/efficiency versus optimal use of airspace, including weather and environmental constraints.

It would seem that the eventual migration of the Descent Advisor functionality would be the likely target for weather integration of high resolution terminal winds and wind shear zones. Tools that help determine compression spacing needs would also likely need similar weather information integration.

REDAC Review

Nothing noted

Weather/ATM Integration Conference Review

A key finding from the report was the need for common de-conflicted forecast winds throughout descent. This was specifically illustrated in the finding that NextGen Network Enabled Weather (NNEW) needs to provide wind observations along descent approaches to support high density operations, and analysis needs to be conducted to determine the performance requirements of these wind observations.

Conference attendees noted that strong winds, combined with wind shear between vertical layers, lead to trajectory complexity that limits the ability of human controllers to maintain high density operations. In order to address the super density compression problems resulting from these wind conditions, controllers need automation assistance. This automation will require accurate and timely wind observations along descent approaches.

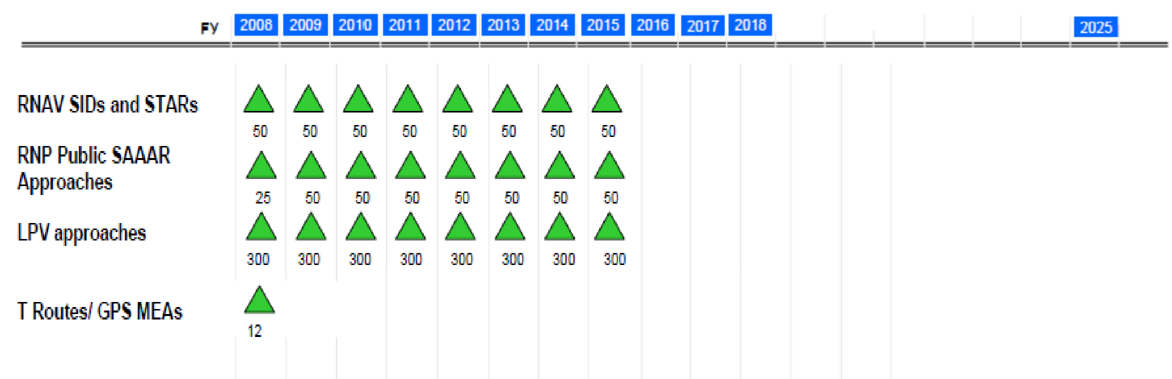
During "nominal" days, weather information is needed to support high density operation automated capabilities (e.g., merging and spacing, Continuous Descent Approaches (CDA), wake vortex procedures, runway configuration management). For example, CDAs and wake vortex avoidance are anticipated to create high temporal and spatial wind observation and reporting requirements. These and other SDO routine weather requirements need to be determined.

It is noted that the Weather/ATM Integration Conference report findings are consistent with the IWP language and interpretation for weather integration for CDAs.

<u>Far-term Capabilities</u>

None currently planned

A-3.3 Capacity Management



<u>Near-term Commitments</u>

RNAV SIDs and STARs

This will provide additional Standard Instrument Departures and Standard Terminal Arrival Routes based on increased RNAV equipage at more locations.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

RNP Public SAAAR Approaches

This will provides additional RNP public Special Aircraft and Aircrew Requirements based approaches at more locations.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

LPV Approaches

This will provide vertically guided approaches at more locations. When vertical guidance is not possible, an LP approach is provided.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

T Routes/GPS Minimum enroute Altitudes (MEAs)

This will provide RNAV routes (Tango routes and GPS MEAs) in support of Airspace Management Program and industry requests.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

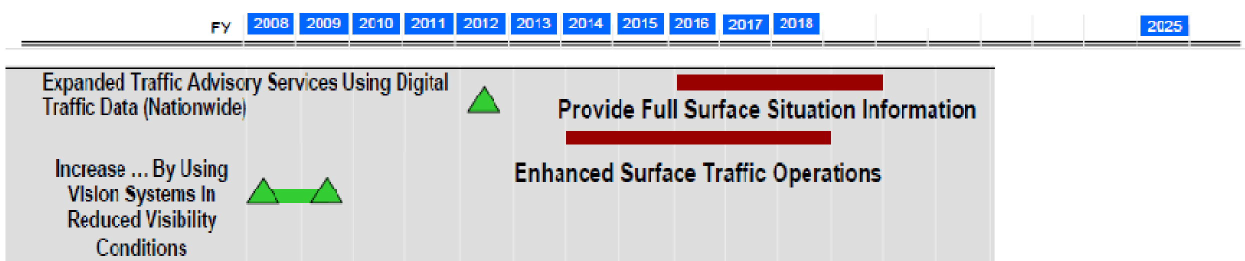
<u>Mid-term Capabilities</u>

None currently planned

<u>Far-term Capabilities</u>

None currently planned

A-3.4 Flight and State Data Management



<u>Near-term Commitments</u>

Expanded Traffic Advisory Services Using Digital Traffic Data (Nationwide)

Surrounding traffic information will be available to the flight deck, including Automatic Dependent Surveillance (ADS) information and the broadcast of non-transmitting targets to equipped aircraft. Surveillance and traffic broadcast services will improve situational awareness in the cockpit with more accurate and timely digital traffic data provided directly to aircraft avionics for display to the pilot.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

Increase Access, Efficiency, and Capacity by Using Vision Systems in Reduced Visibility Conditions

Vision systems will enable more aircraft to land, roll out, taxi, and take off in reduced visibility conditions, thus increasing access, efficiency, and capacity.

Weather Integration Considerations – Infrastructure Roadmap (IR)

None listed

Mid-term Capabilities

A-3.4.1 Provide Full Surface Situation Information

Automated broadcasts of aircraft and vehicle positions to ground and aircraft sensors/receivers will be used to populate a digital display of the airport environment. Aircraft and vehicles will be identified and tracked, providing a full comprehensive picture of the surface environment to the Air Navigation Service Provider (ANSP), equipped aircraft, and Airline Operations Centers (AOC/FOCs).

Decision support tool (DST) algorithms will use this enhanced target data to support identification and alerting of those aircraft at risk of runway incursion. This surface situation information will complement visual observation of the airport surface. Service providers, AOC/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 can be difficult because of several factors, including, but not limited to poor visibility caused by weather or nighttime conditions.

General Comment

Although the above description would suggest that this OI is only about displaying surface traffic information to pilots, dispatchers and controllers, the underlying OI and EN would lead one to believe that there are traffic management decision support tools that are part of, or associated with, this capability. Consequently, the associated weather integration needs will be viewed from that traffic management DST perspective. That integration of airport weather, both current and forecast will be needed to develop a complete picture of airport operation. In the development of a plan for airport operations, weather is an integral part.

Framework Assumptions (AOC/FOC= Airline/Flight Operations Center, ATC = Air Traffic Control, PIC = Aircraft)

Today / Near-term (current to 2010)

- Surface operations are human based at the present time.
- Weather information is based on METAR for current conditions and TAF for forecast weather.

Mid-term (2010-2018)

Far-term (2018-2025)

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

None listed

<u>Issues/Risks/Comments</u>

- No weather supported by this timeframe

<u>Comments</u>

See the General Comment above, and note the REDAC and JPDO Weather/ATM Integration Conference reports below, all in light of the supporting OI and EN.

The level of detail required of both observed and forecast weather will be much greater than current METARs and TAFs. Weather forecast will need to be tailored to the airport needs and operations.

<u>Integrated Work Plan (IWP) Review</u>

There are two Integrated Work Plan (IWP) Operational Improvements (OIs) and supporting enabler elements (ENs) identified that support the IFTE NIP Swim Lane capabilities for providing full surface situation information. These are highlighted below.

OI-0331 Integrated Arrival/Departure and Surface Operations (2018) describes the integration of advanced arrival/departure flow management with advanced surface operation functions to improve overall airport capacity and efficiency. Associated decision support tools enable ANSP flow managers to work collaboratively with flight operators and with ANSP flow contingency managers to effectively manage high capacity arrival and departure flows in the presence of various weather conditions.

EN-0026 - Surface Movement Decision Support - Level 2 Mid-term (2015) describes tools needed to enable safe and efficient flow of aircraft and ground equipment on the surface. This includes decision support automation for efficient flow management, real time information distribution, such as runway braking action reports, and ground-based runway incursion detection and alerting.

<u>REDAC Review</u>

<u>(4.4.2.3) Finding:</u> Integrating Airport Surface and Terminal Area Weather and ATM Tools could improve system performance and capacity.

Surface and terminal airspace operations could be improved if weather and traffic information were combined into a single system that computes the impact of the weather on potential traffic management decisions and provides the results in simple, easily understood display of decision options.

<u>Recommendations:</u> 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.

Conduct research on enhancing the Traffic Management Advisor (TMA) to achieve a weather sensitive arrival planning tool.

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.

Comment

It would seem that REDAC deemed the impact of weather on potential traffic management decisions to be important. While this is true, the DST should provide the guidance and the user of the DST should ultimately determine the impact.

Weather/ATM Integration Conference Review

The JPDO Weather/ATM Integration Conference provided a significant amount of feedback concerning runway surface information, as detailed below.

Section 2: Airport Operations

Finding: Need for improved forecasts of runway conditions.

The next area of research which was agreed upon was the need for better sensing and runway condition forecasts. With improved forecast reliability and accuracy, operators would be able to better trust in the weather information they were given. This would then allow them to more efficiently plan around anticipated hazardous weather events.

Finding: 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.

Finding: De-icing activities need reduced costs and increased flexibility.

Continued research toward more efficient and environmentally-friendly anti/deicing methods/technologies was seen as highly beneficial by the group. An improvement toward more environmentally-friendly methods/technologies was seen as having the dual benefits of decreased costs and increased flexibility in usage. Increased efficiency of anti/deicing methods would also increase the efficiency of overall operations. Additionally, alternative delivery methods of both runway and aircraft deicing fluids were determined to be necessary avenues of research for the same reasons.

The group concluded that deicing by aircraft type would be advantageous in two primary ways. First, this would help to increase the safety of operations by maximizing the benefits gained. Second, this would help to reduce cost and economic impact by minimizing potential inefficient use of deicing fluids.

Recommendation: Address runway sensors that are non-representative of actual conditions. Improve runway forecasts' accuracy and reliability.

Recommendation: Develop and validate a requirements matrix to address user needs for weather as integrated with various surface movement operations.

Recommendation: Deicing should be standardized by aircraft type.

Finding: Derive and validate metrics from operational users.

The metrics to use would be the ability to predict delta from scheduled departure time from the gate and off runway during weather impacted operations. It is important that additional metrics be both derived and validated from operational users to insure their accuracy and applicability.

Weather Integration focus from the Airport Operations sub group

While the group's findings were on envisioned improvements in runway condition forecasts and de-icing techniques, via research initiatives, true weather integration into current operational or planned decision support functionality was not identified. The high confidence in forecast perception for runways is noted and must be well considered when weather information fidelity performance requirements are identified. The integration of runway/taxi/ramp/gate surface temperatures together with the onset/cessation of icing conditions into airport management decision tools would provide greater proactive guidance which in turn could lead to greater surface movement and de-icing efficiencies.

The group did start to address more weather integration issues with the identification of the numerous surface movement activities that should be integrated with regard to weather impact. Each of the identified activities will have decision issues in time and location on the airport that may be affected by weather. These need to be examined for commonality so that differing activities affected by weather in similar ways can be better coordinated.

The discussion on metrics was very important in regard to weather integration in that operational metrics must be considered over more traditional meteorological metrics. This will eventually prove user perceived value. Operational metrics of user value will also drive weather integration fidelity performance requirements.

Trajectory Based Operations (TBO)

Finding: Need to quantify the effect of weather on the ability for aircraft to meet 'wheels off time' while still on the ground, to maintain a given trajectory, and to arrive at designated waypoints at expected points in time.

The ability for an aircraft to meet 'wheels off time' initiates a TBO construct. The continued ability of an aircraft or a flow of aircraft to maintain a given trajectory and/or arrive at designated waypoints at expected times are equally critical to successful TBO. Current weather, forecasted weather and its affect on aircraft performance will disrupt all these abilities. Equipage and unique agency concepts of operations will need to be taken into account.

Recommendation: 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 enhanced through the combined use of ground vehicles and aircraft sensors to determine position.

Recommendation: 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 has authority to take the risk, levels of action (go/no/go) or can there be shades (red/yellow/green).

Super Density Operations (SDO)

A major conclusion identified by the Super Density Operations (SDO) group was that weather integrated into various SDO (automated) solutions may be different by location – due to varying operational nuances in major terminal areas. Weather research initiatives for SDO must be an early NextGen priority to identify specific airport impacts (both today and in NextGen).

It was also noted that a lack of wind velocity (calm wind conditions) can increase runway occupancy time and be considered "off-nominal." Airport surface weather needs to be considered along with the weather conditions on approach and departure trajectories to maximize the efficient utilization of both airports and airspace.

Weather Integration focus from the SDO sub group

It seems that the significance of the comments from the SDO sub group is that each airport will likely have its own set of important operational thresholds. While the weather fidelity or performance attributes can be the same (such as from the 4-D Wx SAS), the impact trigger thresholds will vary and as such, decision support tools should be made to allow for adaptative control with regard to weather information. This could be a 'pull' type set up from the tool end or a 'push' type set up from the 4-D Wx SAS end.

A-3.4.2 Enhanced Surface Traffic Operations

Data communication between aircraft and Air Navigation Service Provider (ANSP) will be used to exchange clearances, amendments, requests, NAS status, weather information, and surface movement instructions. At specified airports data communications is the principal means of communication between ANSP and equipped aircraft.

Among the information being sent to the aircraft and integrated into on-board aircraft systems will be On-Demand NAS Information from the Super Computer Aided Operational Support System (S-CAOSS), the tower platform for Data Comm Program Segment 1 (NAS EA OI: 103305, 2013-2017). Terminal aeronautical information will be available to equipped aircraft and provided on demand via data communications between the FAA ground automation and the aircraft. This includes current weather, altimeter settings, runways in use, and other departure and destination airport information.

Framework Assumptions (AOC/FOC = Airline/Flight Operations Center, ATC = Air Traffic Control, PIC = Aircraft)

Today / Near-term (current to 2010)

Mid-term (2010-2018)

Far-term (2018-2025)

Comments

- The question of how will weather be used/integrated into DSTs for tower taxi route generation needs attention. It would appear that the condition of the airport runway, taxiway and ramp surfaces will play a role in determining how quickly an aircraft can move between two points on the airport surface, and that DSTs (e.g., taxi route generators) which calculate and suggest surface movement trajectories have to take this into account. Similarly, changing surface weather conditions and/or surface/boundary layer weather must have an influence on taxi route generation, especially when shifting combined with arrival and departure flows drive runway configuration changes. Improved airborne observation capabilities including near real-time wind, temperature, humidity and icing may be used to improve understanding of surface weather conditions and its impact on aircraft movement on the airport surface.
- The generation of initial and revised departure clearances and taxi route clearances direct to the aircraft will require changes to both aircraft and aircraft operator, automation, e.g., aircraft communication management units and possibly AOC/FOC operations management automation systems.

Weather Integration Considerations – Infrastructure Roadmap (IR)

Enhanced Forecasts - Surface Conditions and Terminal Weather.

Issues/Risks/Comments

- Ground-to-Air Data Communications
- NextGen WP1 – Enhanced Forecasts – Surface Conditions
- 4-D Wx SAS - Enhanced Observations
- Sensors feeding the 4-D Wx SAS: Wind shear detection (e.g. LL-WAS), ASR-WSP, TDWR, LIDAR, ASR-8/9/11, NEXRAD, F-420, DASI, ASOS, AWOS, AWSS, SAWS, NextGen Surface Observing

Integrated Work Plan (IWP) Review

There is an Integrated Work Plan (IWP) Operational Improvement (OI) and supporting enabler element (EN) identified that support the IFTE NIP Swim Lane capabilities for providing full surface situation information, both of which are highlighted below.

OI-0327 - Surface Management - Arrivals/Winter Ops/Runway Configuration (2018) calls for improvements in efficiency and safety of surface traffic movement, with a corresponding reduction in environmental impacts. Efficiency of surface movement is increased through the use of automation, on-board displays and data link of taxi instructions on arrival to properly equipped aircraft to reduce delay and environmental impacts and improve safety. This OI assumes the development of surface automation that is fully integrated with airborne operations and applies this to surface management operations.

EN-5004 - Airport GSE Surface Management System (2013) suggests that surveillance systems, either active or passive, will track Ground Support Equipment (GSE) on the airport surface. GSE location data will be available to the Ramp Operator, Air Navigation Service Provider (ANSP), and pilots as needed. Specifically, pilots will be aware of GSE movements which will be shown on flight deck situational displays. The system is needed to support low-visibility aircraft taxi operations, collision avoidance, and surface management. The system provides for interoperability between different types of GSE and aircraft.

<u>Comment</u>

The importance of this initiative is the communications aspect, and not necessarily the weather information aspect. There needs to be adequate bandwidth provided for the communication of weather information so that it can then be integrated. It is understood that other informational sources will command higher availability.

<u>REDAC Review</u>

Nothing noted

<u>Weather/ATM Integration Conference Review</u>

Nothing noted

<u>Far-term Capabilities</u>

None currently planned

A-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. Collaborative Air Traffic Management (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 National Airspace System (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-analysis.

A-4.1 Flight Contingency Management

<u>Near-term Commitments</u>

Airspace Flow Program

Enroute congestion due to weather will be reduced by equitable management of departure times (e.g. ground delay to an airspace volume).

Integrated Surface Data: (ATL, ORD, and JFK)

Better surface flight event knowledge will be integrated into decision support tools, to improve accuracy of down-stream demand estimation and improve the use of flow management tools.

Reroute Impact Assessment and Resolution

Automation will be provided to support identification of flight-specific reroutes for weather related congestion and assessing the impact of those planned reroutes in resolving the congestion problem.

Execution of Flow Strategies

Exchange of aircraft-specific reroutes (required to resolve enroute congestion) between TFM and ATC automation.

International Flight Object Demonstration

This demonstration is part of the development of the U.S. flight object and collaboration on an international standard. It will show how, in a System Wide Information Management (SWIM) environment, subscribing to the flight object can provide continually updated status and be a vehicle for negotiation for Air Navigation Service Providers (ANSPs), AOC/FOCs, airports, and others.

Mid-term Capabilities

A-4.1.1 Continuous Flight Day Evaluation

Performance analysis, where throughput is constrained, is the basis for strategic operations planning. Continuous (real time) constraints are provided to ANSP traffic management decision support tools and National Airspace System (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.

Needs/Shortfall

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 decision support tools is required in continuous real time. These tools will be used to monitor, evaluate, and adjust traffic flow management initiatives (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 enroute airspace capacity.

Operational Concept

ANSPs and users collaboratively and continuously assess (monitor and evaluate) constraints (e.g., airport, airspace, hazardous weather, sector workload, Navigational Aid (NAVAID) outages, security) and associated TMI mitigation strategies. Users and the ANSP dynamically adjust both pre-departure and airborne trajectories in response to anticipated and real time constraints. The 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. The ANSP and users use (real time) constraint information and these mitigation strategies to increase operational predictability and throughput.

ANSP automation traffic management decision support tools 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.

Design/Architecture

The TFMS infrastructure will serve as the focal point for continuous flight day evaluation capability. The performance monitoring and evaluation tool suite will be integrated with other TFM decision support capabilities being developed to facilitate the identification of TFM problems, the generation and assessment of potential resolution strategies, and automation-based execution of TMIs. These other capabilities will include support for such features as reroute impact assessment, miles-in-trail impact assessment, integrated TMIs (this can include combinations of altitude, speed, and rerouting maneuvers), progressive planning (the use of multiple TMIs applied progressively to a particular traffic flow), future traffic display and congestion prediction.

Weather Integration Considerations – Infrastructure Roadmap (IR)

None listed

Weather Involvement – Preliminary Review: TFM Concept Engineering Plan

Performance analysis, where throughput is constrained, is the basis for strategic operations planning. Continuous (real time) constraints are provided to Air Navigation Service Provider (ANSP) traffic management decision support tools and National Airspace System (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. Concept Engineering initiatives classified in this Solution Set and promoting this Capability are listed in the table below

Table A-5 CATM Concept Engineering Initiatives

Organization	**Topic**	**Concept Maturity**
CSC	Enhanced Flight Segment Forecasting	CE
Metron Aviation	Airborne Delay Research	

Table A-5 CATM Concept Engineering Initiatives

Organization	**Topic**	**Concept Maturity**
Metron Aviation	Integrated Program Execution (IPE)	FSD
Metron Aviation	Integrated Program Modeling (IPM) Phase 2	PD
Metron Aviation	NextGen of FSM slot assignment logic	
Metron Aviation	Pre-day of Operations TFM concepts	
Metron Aviation	System Integrated TMIs	CE
Volpe	Analyze Uncertainty in Sector Demand Prediction	CE
Volpe	Prototype a New Metric for Sector Alerts	CE

Based on the programs listed in the table above, the following programs may require integration of weather information in current or future phases:

1. Airborne Delay Research (Metron Aviation, CE Phase): The project proposes the development of an application of existing algorithms for measuring where airborne delays occur, extension of prototype simulation capabilities to develop an Airspace Congestion Predictor (ACP), metrics for measuring existing airspace congestion, a capability to predict airborne delays and congestion, metrics for comparing candidate TFM strategies, and potential enhancement to Jupiter. Potential weather integration needs include but are not limited to historical weather data for areas of weather impacted airspace.

2. Analyze Uncertainty in Sector Demand Prediction (VOLPE, CE Phase): The current methods used for of sector demand prediction are subjected to "flickering" as a sector goes in and out of alert status. This reduces traffic managers' confidence in the TFMS sector demand predictions. Understanding the uncertainty in the predicted demand will lead to more usable demand predictions. Previous work characterized the uncertainty in predictions of airport demand, but this analysis will analyze the uncertainty in sector demand. The results of the analysis will present predicted future demands to traffic managers in a more useful way that avoids misleading predictions and unnecessary workload. Potential weather integration needs include examining the impact of various weather phenomena such as convective weather, turbulence and in-flight icing to allow for more dynamic predictions of uncertainty in sector demand.

3. Integrated Program Modeling (IPM) Phase 2 (Metron Aviation, PD Phase): Integrated Program Modeling (IPM) is an attempt to display the interactions between AFPs and GDPs in

terms of demand profiles and to aggregate delay statistics before programs are implemented. IPM Phase I, which was deployed in spring of 2008, provides the capability to model the effects of a program on multiple resources. The Phase I capability is useful for analyzing the effects of one AFP on many airports, or one GDP cancellation on many FCAs. The second, known as the IPM Phase II prototype will have the ability to see the effect of multiple AFPs on airport demand, will provide total delay estimations for combinations of GDPs and AFPs and effectiveness comparisons of AFPs versus GDPs. IPM will be a tool to support Traffic Managers to validate decisions to implement traffic management initiatives (TMIs) or to avoid unnecessary programs. Potential weather integration needs include examining the impact of various weather phenomena such as convective weather, turbulence, in-flight icing and ceiling and visibility to allow for more dynamic assessments of TMIs.

<u>4. Pre-day of Operations TFM concepts (Metron Aviation):</u> There are a number of airports that experience congestion on a regular basis. Some of this congestion can be traced to too many flights being scheduled collectively by all customers during busy time periods. This project will explore and evaluate concepts for conducting Traffic Flow Management activities before the day of operations using predominately airline schedule information and/or historical data. Potential weather integration needs include but are not limited to long range forecasts (12-24 hours) of convective weather, turbulence, ceiling and visibility.

<u>5. System Integrated TMIs (Metron Aviation, CE Phase):</u> Congestion problems on a national scale are usually remedied through Ground Delay Programs (GDPs), Airspace Flow Programs (AFPs), and national-level reroutes. These TMIs are highly structured and robust, but only address the management of demand at the constrained resource. Each program may produce residual effects at different resources throughout the NAS. System-Integrated TMIs (SIT) will research the interactions of multiple initiatives for system-wide effects. . The SIT effort will examine interactions between over-lapping initiatives. It will provide insight that will create a foundation for a pre-implementation system-impact assessment tool that provides common situational awareness, increases certainty on how multiple TMIs may interact, and provides adequate metrics to facilitate planning. Potential weather integration needs include examining the impact of various weather phenomena such as convective weather, turbulence, in-flight icing and ceiling and visibility to allow for more dynamic assessements of TMIs.

<u>Weather Involvement – Preliminary Review: MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities</u>

Mid-term continuous flight day evaluation will provide performance analysis and improvement capabilities which address two distinct operational areas: current day congestion prediction and decision-making; and enhanced post operations analysis.

<u>Current Day Congestion Prediction</u>

Enhancements to congestion prediction will focus on improving demand and capacity prediction accuracy by integrating data from multiple sources to get a better picture of the status of the NAS. Integration of surface event data from terminal systems will improve predictions on flight departures, while integration of trajectory data from other sources, such as enroute automation, will improve accuracy and ensure consistency with the TFM-specific trajectory modeling capability.

Demand prediction will be further improved through enhanced modeling capabilities, including flight trajectory and Miles-in-Trail (MIT) restriction modeling. Modeling enhancements will provide the basis for what-if analysis and planning that will allow traffic managers to better understand the potential impacts of changing flight patterns in the NAS. Automation and displays will be enhanced to account for uncertainty and risk in predictions by depicting probability distributions, as well as to allow traffic managers to view graphical depictions of current and predicted future flight positions in conjunction with convective weather forecasts. TMs will have access to improved real time situational awareness of NAS conditions through the use of a 'NAS Performance' dashboard function. Automation will allow TMs to select from various performance metrics for display on a tailored, web-based display page, providing dynamically updated NAS situational information in a concise, integrated fashion. This display capability will be able to be tailored by Traffic Management Unit (TMU) personnel to individual requirements.

Capacity prediction improvements are another significant enhancement for TFM in the mid-term, with the most significant improvement resulting from the enhancement and integration of weather prediction information. This will allow weather information to be used not only in capacity predictions, but in demand prediction and aircraft trajectory modeling displays as well, further improving the TMs understanding of NAS status. Later in the mid-term, automation will predict sector capacity based on traffic flows and weather predictions, instead of using the Monitor Alert Parameter as a proxy for sector capacity.

Post Operations Analysis

In the mid-term, Post Operations Analysis improvements must first focus on establishing a baseline data collection, storage and analysis capability. Once this is accomplished, it will enable improvements in the ability to provide significant next day post operations analysis and operational improvements. NAS status information (such as congested routes, severe weather, and runway visibility range information) will be gathered from various TFM, Enroute Automation Modernization (ERAM) and Terminal domain automation systems and stored according to a consistent and common information model, supporting 'what-if' analysis and prediction through stored and ad-hoc queries. A common meta-data model will maximize the ability to correlate information across multiple sources and domains.

In the later mid-term, automation will evolve to monitor and record traffic flow patterns and the TMIs taken in response to them, in addition to recording NAS situation and performance data. This advanced NAS Situation and TFM planning snapshot capability will provide for more in-depth and timely quality assurance reporting and post-ops analysis of TMI effectiveness. In the far-term, this capability could evolve to allow automation to perform comparative analysis of potential resolution actions by showing several courses of action that have historically been suggested given similar circumstances, and the historical effectiveness of each, improving the information provided to TFM planners.

Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap

Weather Integration into Enhanced Congestion Prediction

More accurate predictions of NAS resource congestion (enroute sector, airspace flow evaluation area and airport) are a major focus of future Traffic Flow Management concepts. Traffic managers use congestion predictions to establish the type, timing and scope of TMIs. Because of the uncertainty in today's predictions, TMs often implement highly conservative strategies as a hedge against worse-than-forecast conditions.

Uncertainty in future resource congestion arises from both inaccuracies in estimating future demand, and from very limited capability to predict the future capacity of NAS resources during adverse weather. Demand predictions today do not even fully account for the impact of currently approved TMIs (for example MIT or arrival fix restrictions), and certainly do not attempt to estimate the impact of future TMIs that may be imposed as new weather constraints develop. Quantitative, dynamic predictions of resource capacity are not currently available and as a result, TMs must subjectively estimate the impacts of adverse weather on future airport operations rates and enroute airspace capacity.

Sector Demand Prediction

Probabilistic resource demand predictions must model not only currently approved TMIs but the likely effects of future TMIs that will be needed in response to weather constraints that are worsening or may not yet have developed. To properly model these future flow restrictions, a NAS-wide model accounting for time-varying future resource capacities and total (scheduled and pop-up) demand is needed. Since the skill of the demand and weather constraint predictions will generally improve rapidly for shorter look-ahead times, this model must cycle rapidly (~ twice per hour) in order to take advantage of the improving information on future constraints. Development of such a real time model that fully integrates state-of-the-art weather predictions, weather-impact translations and traffic demand forecasts is a major undertaking that does not appear to be adequately supported in the current weather and TFM research portfolios.

Resource Capacity Prediction

"CATM Report 2007" states that CIWS forecast data will be used in the mid-term timeframe to predict the reduction in expected resource capacity. Further, for each resource and each look-ahead time, the probability distribution function of the capacity will be determined by TFM. This may be implemented for enroute sectors as a reduction in the Monitor Alert Parameters (MAP), based on the weather coverage, route blockage or other considerations. Realizing a robust capacity prediction capability will require major effort in at least three areas.

- Continued progress in diagnosing and forecasting relevant weather phenomena over the 0-8 hour time scales needed for TFM is essential with research focused on extending the look-ahead time for convective weather forecasts to 6-8 hours, and on improved 0-2 hour "nowcasts" of turbulence and airport weather conditions (ceiling and visibility, winds, winter precipitation) that effect capacity.
- Validated models for translating the weather information into quantitative resource constraint metrics are required. Research in this area is in its infancy. For airspace constraints, it is believed that approaches based on algorithms for reduction of sector

MAPs are problematic. MAPs are widely recognized to be subjectively determined and inconsistent across the NAS, even during nominal conditions. Scaling of MAPs to account for weather impacts must account for the directionality of major flows within a sector and, that the associated weather blockage that may be quite different for different major flows. Objective models for airspace capacity during both nominal and off-normal conditions are likely to be more useful (e.g., Welch et al., 2007; Martin et al, 2007; Song et al., 2007) but these approaches must be integrated, validated and adapted as necessary to future, more automated ATC paradigms. Augmented research on the impacts of non-convective weather phenomena (turbulence, icing) on airspace capacity is needed, as is a more comprehensive capability for predicting weather impacts on future airport operating rates.

- Viable methods for estimating and conveying the uncertainty of future resource capacity predictions must be defined. This will require tightly coupled effort involving the meteorological forecasting and ATM research communities. It is felt that "ensemble" approaches are most likely to be effective – that is, a set of discrete weather forecasts will be developed that span the expected range of future scenarios, and these will be translated individually to associated estimates of capacity constraints on specific NAS resources. From these ensembles, appropriate metrics and visualizations of uncertainty can be transmitted to automated decision support tools and TMs.

Route Blockage and Route Congestion Prediction

In the mid-term time frame, route blockage will be determined for airport departures and arrivals and for transition and high-altitude enroute operations. This capability will expedite Departure Flow Management, in-flight rerouting and arrival management. While these concepts are based on the Route Availability Planning Tool (RAPT) already in operational use at New York City airports, considerable effort is needed to adapt the concept to departure operations at other airports, to integrate it with other information on departure constraints (surface and downstream) and to extend it to enroute and arrival operations.

A major first step is to develop flight-specific route blockage prediction capability which is tied to the aircraft trajectory ("wheels up time", arrival-time at flight path "way points") and to an efficient capability to determine viable alternatives when the filed route of flight is blocked by adverse weather. Route congestion prediction will require the additional development of algorithms for translating "partial blockage" scenarios into estimates of required Miles (or Minutes) in-trail constraints. The approach described by Martin et al. (2007) for calculating the impact of partial route blockage on route throughput could be interpreted in terms of increased miles-in-trail restrictions although the authors do not discuss this point explicitly nor show any experimental data to confirm this interpretation. Significant additional research is needed to determine what transpires operationally in route usage when the route availability determined by this method is intermediate between 0 and 1. More generally, there is an urgent need to validate the route blockage models for airspace usage (e.g., storm impacts on routes, merge points, use of adjacent routes carrying traffic in a given direction when one of those routes is blocked) under various degrees of intersections by weather avoidance fields (WAF).

Work (similar to the RAPT concept) needs to be expanded to explicitly forecast when arrivals deviating into departure airspace will become an operational constraint to departures. There is a research item that needs to be considered:

> There is a need to provide an enhanced capability for tactical adaptive, incremental traffic routing as a complement to "strategic" flight planning that requires much higher accuracies in 2-8 hour convective forecasts than seems achievable in the near-term. This was recommended by the REDAC WAIWG (REDAC, 2007). Also, the approach used to forecast Airspace Flow Program (AFP) throughput could be used to forecast throughput rates for "overlap AFPs" under investigation currently by the CDM Flow Evaluation Team (FET). A critical next step in evaluating the operational applications and benefits of this AFP throughput forecast will be to exercise the route blockage/flow rate restriction model with CIWS forecast products, as opposed to actual VIL and Echo Tops data used for the results reported in Robinson, Martin, Evans and DeLaura (2008). The use of specific TMIs for appropriately modulating demand through AFP regions, based on guidance from the AFP throughput model, needs to be modeled and assessed for multiple real weather case scenarios. This work would benefit from the participation from operational Traffic Management subject matter experts (SMEs). To the extent possible, benefits of the dynamic AFP rate concept would be assessed relative to actual NAS operations on the case days considered. This research work should be accomplished in close collaboration with the work underway by the CDM Flow Evaluation Team (FET) to develop "adaptive AFP" concepts.

<u>Weather Integration into Automated Airspace Congestion Resolution</u>

Automated airspace congestion resolution concepts build on improved customer information exchange and enhanced congestion prediction capabilities to provide automated assistance to TMs in developing and executing reroute and delay programs.

In the mid-term time frame (2010-2015) TFM automation will disseminate probabilistic demand and capacity predictions for all monitored NAS resources to TMs and NAS customers. TMs will specify flow evaluation areas (FEA) indicating the airspace volumes where demand may need to be reduced, and will notify customers via a Planning Advisory. After customers review this information and submit prioritized flight preferences, TMs will use the Automated Airspace Congestion Resolution capability as an aid in resolving the predicted congestion. TMs can guide the automated solution via input on preferred resolution strategies (ground delay vs. rerouting), special guidance for individual airports, maximum ground delay and maximum distance increase for reroutes.

In the initial phase (2011-2014), the current FAA plan is to implement an initial Automated Airspace Congestion Resolution (AACR) capability in which the TMs will identify the Flow Evaluation Areas (FEAs) and then the automation will propose a single, one-time resolution that will attempt to resolve the congestion that arises from the FEA all at once.

In the post 2011-2014 time frame, TFM automation will identify the congestion problems and candidate FEAs and will propose incremental resolutions that maintain congestion risk at an acceptable level, while retaining the flexibility to modify the or expand the resolutions as the future demand and constraint situation evolves. This approach will presumably reduce the number of flights affected by the initial TMIs. Thus if the congestion problem turns out to be less severe than originally forecast, the overall impact on customer operations will be reduced.

Weather Integration into Phase 1 Mid-Term Automated Airspace Congestion Resolution

An efficient "one time" automated congestion resolution would require high fidelity forecasts of the weather out to 0-6 hours as well as accurate translation of these forecasts into capacity impacts. Although multi-hour CoSPA forecasts of convection will be introduced during this phase, it is to date uncertain as to whether their accuracy (or the accuracy of necessary weather-capacity impact models) will be sufficient to support such onetime resolutions. In addition, errors in the capacity forecasts will translate into uncertainty about what future flow constraints will be necessary. This uncertainty in turn will result in errors in demand prediction that will also make one time, automated congestion resolution strategies very problematic.

One view is that in the 2010-2015 timeframe, the major emphasis should be on improving the performance of human TMs through the provision of increasingly high quality information on future constraints. This capability will fall out of the enhanced information exchange and congestion prediction thrusts described previously, and will lead to both better NAS operational performance and "real-world" experience with strategies for exploiting the enhanced information to improve congestion resolution.

It is recommended that proposed concepts for these Phase 1 congestion resolution strategies be vetted through analysis and HITL simulations using realistic projections for future weather forecast capabilities. This should be accomplished as a precursor to any investment decision in this area to quantify the frequency with which the automated congestion resolution produces substantive investment decisions.

A-4.1.2 Traffic Management Initiatives with Flight-Specific Trajectories (Go Button)

Individual flight-specific trajectory changes resulting from Traffic Management Initiatives (TMIs) will be disseminated to the appropriate Air Navigation Service Provider (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.

Needs/Shortfall

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.

Operational Concept

Traffic Flow Management (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.

Design/Architecture

Traffic managers and applications within the TFMS infrastructure will interact with air traffic controllers and Enroute Automation Modernization (ERAM) to implement this capability. TFMS automation will support identification of flights that are subject to TMIs. The TFMS automation will then communicate the requested flight plan adjustments to ATC automation for tactical evaluation, approval, and execution of those flights subject to TMIs, to bring them into conformance with the TMIs.

Weather Integration Considerations – Infrastructure Roadmap (IR)

While no weather integration considerations were identified in the Infrastructure Roadmap, space weather alerts should be integrated into TFM to allow for aircraft altitude adjustments during significant solar activity.

Weather Involvement – Preliminary Review: TFM Concept Engineering Plan

No specific plans noted.

Weather Involvement – Preliminary Review: MITRE: Initial Evolution Analysis for Mid-Term Operations and Capabilities

TFM automation will continue to incorporate enhancements, including decision support tools to enable the collaborative process among service providers and NAS users in the development and implementation of congestion resolutions. Decision support tools 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 miles-in-trail. The automation will propose to the traffic manager 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 traffic manager to enable the decision to modify, cancel or execute a given initiative.

Once the traffic manager decides on the initiative, flight-specific changes are disseminated with automation support (“Go Button”) 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).

Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap

No specific plans noted.

Far-term Capabilities

TBD

A-4.2 Capacity Management

<u>Near-term Commitments</u>

Currently, there are no defined near-term commitments.

<u>Mid-term Capabilities</u>

A-4.2.1 Improved Management of Airspace for Special Use

Assignments, schedules, coordination, and status changes of special use airspace (SUA) are conducted machine-to-machine. Changes to status of airspace for special use are readily available for operators and Air Navigation Service Providers (ANSPs). 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.

<u>Needs/Shortfall</u>

Both National Airspace System (NAS) service providers and NAS users need a common, accurate, and timely understanding of the status of SUAs so that their collaborative planning and decision-making can be done both efficiently and effectively. Currently, although most daily SUA status information is readily available in electronic form for immediate use by enroute and/or traffic flow management (TFM) automation via the Federal Aviation Administration's (FAA's) Special Use Airspace 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 Department of Defense scheduling agencies and SAMS.

<u>Operational Concept</u>

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 machine-to-machine 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 decision support tools, integrated with machine-to-machine 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 SUA-encoded data. The SUA status is available via uplink to the cockpit in graphical and automation-readable form, supporting pre-flight and in-flight planning.

<u>Aircraft and Operator Requirements</u>

There are no aircraft or operator requirements associated with this capability. Operators can choose the degree to which they use the SUA scheduling information in their flight planning. Operators choosing to participate in this capability must interface their airline operations center with SWIM. Aircraft equipped with Flight Information Service-Broadcast (FIS-B) can receive SUA status in the cockpit.

<u>Design/Architecture</u>

The source of information regarding the definition and status of SUAs is likely to be SAMS. This information will be shared among NAS stakeholders during flight planning, supported by the SWIM infrastructure. The Surveillance Broadcast Services (SBS) will distribute this information to the aircraft.

Weather Integration Considerations – Infrastructure Roadmap (IR)

None listed

Weather Involvement – Preliminary Review: TFM Concept Engineering Plan

None listed.

Weather Involvement – Preliminary Review: MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities

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 machine-to-machine 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 decision-support tools, integrated with machine-to-machine 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 SUA-encoded data. The SUA status is available via uplink to the cockpit in graphical and automation-readable form, supporting pre-flight and in-flight planning.

No specific weather integration needs were identified.

Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap

None listed.

Far-term Capabilities

TBD

A-4.3 Flight and State Data Management

Near-term Commitments

Currently, there are no defined near-term commitments.

Mid-term Capabilities

A-4.3.1 Trajectory Flight Data Management

Trajectory Flight Data Management will improve the operational efficiency and increases the use of available capacity by providing for improved flight data coordination between facilities. This will enable access to airports by readily facilitating reroutes. Additionally, it will support more flexible use of controller/capacity assets by managing data based on volumes of interest that can be redefined to meet change to airspace/routings. Trajectory Flight Data Management will also provide continuous monitoring of the status of all flights – quickly alerting the system to unexpected termination of a flight and rapid identification of last known position.

Needs/Shortfall

The current flight data management systems are a related set of functionalities that are not complementary, limiting the ability of various Air Traffic Management (ATM) processes to link decisions. The current system has limited capacity, which forces a reliance on Official Airline Guide (OAG) for future schedules and the use of historical routings in the strategic flow planning. Computational efficiencies required by legacy computer systems inhibit the ability to distribute and share flight progressive information and coordination leading to limitations on clearance management. Further, there is a fundamental need to facilitate trajectory negotiation and update in a collaborative manner if both the traffic flow objectives of ANSPs and NAS airspace users' flight preferences are to be met. Currently, ANSPs use a variety of traffic management initiatives (TMIs), scheduling tools, and trajectory-based operations agreements. These achieve the traffic flow management (TFM) goal of balancing air traffic demand with system capacity to ensure the safe, orderly, and expeditious flow of air traffic while minimizing delays. At the same time, airspace users need approved flight plans that match, as closely as possible, their operational needs.

Operational Concept

In trajectory flight data management, there will be complete end-to-end management of the flight from pre-flight to post analysis. Flight planning and filing will be supported up to flight departure. This will replace reliance on OAG for future schedules and historical routing to identify potential flight profiles and will provide information commensurate with development of longer-term strategic flow initiatives. Further, by filing early, the user will receive updates until departure date, identifying changes in constraint status, and permitting early reevaluation and replanning of the flight. This will include restrictions for special events or planned NAS outages. The flight plan management system will use "volumes of interest" to determine the relationship of the projected trajectory and the interest of service providers. This supports the separation assurance and advisory services through more flexible distribution of flight data, the automatic generation of point-outs and the coordination functions for control of aircraft. This move to volumes will also mean that the flight data management system can support user preference from runway-to-runway without requiring any fixed-routing segments for processing. The flight data processing system will increasingly incorporates flight data information provided by the flight deck into the trajectory and conformance modeling, improving the support to service-provider and decision support tools.

Finally there will be a change in the "ownership" of the active profile. Changes to flight profiles beyond the window of the tactical service providers will be negotiated with a strategic planner and updated without requiring tactical service-provider involvement. This will reduce the workload on the tactical-provider while placing responsibility in the hands of strategic-flow, ensuring change will be consistent with current flow objectives.

Design/Architecture

This integrated advancement will leverage new capabilities in TFM and Enroute Automation Modernization (ERAM), as well as allow for expanded opportunities by the flight object to move to a full trajectory flight data management. This will be made possible by the implementation of System-Wide Information Management (SWIM). This implementation will also require the NAS to move to a common information grid structure.

Weather Integration Considerations – Infrastructure Roadmap (IR)

Improved Observations, Enhanced Forecasts and a de-conflicted common weather picture is needed.

Weather Involvement – Preliminary Review: TFM Concept Engineering Plan

Trajectory Flight Data Management will improve operational efficiency by increasing the use of available capacity. Advanced flight data coordination between facilities will maintain access to airports by facilitating reroutes, and supporting more flexible use of controller/capacity assets. By managing data based on volumes of interest, airspace/routings can be redefined to accommodate change. Trajectory Flight Data Management will also maintain continuous monitoring of the status of all flights, quickly alerting the system to unexpected termination of a flight and rapid identification of last known position. Concept Engineering initiatives classified in this Solution Set and promoting this Capability are listed in the table below.

Organization	Topic	Concept Maturity
Metron Aviation	Additional AFP Capabilities and Usage	CE
Metron Aviation	Environmental Modeling & Analysis of TFM performance (fuel burn estimation)	
Metron Aviation	Reroute Impact Assessment (RRIA)	CD
Metron Aviation	Special Use Airspace (SUA) Information Research	

Based on the programs listed in the table above, the following programs may require integration of weather information in current or future phases:

1. Control by CTA (Metron Aviation, CE Phase): The objective of a GDP is to create a managed flow of arrivals within the capacity of the arrival airports constraints. However, the GDPs are implemented at the departure end by assuming that flight operators will prefer to fly the same ETE. This ignores additional constraints that may exist in the airspace or at the departure airport. This research proposes the development of the concept for managing a GDP via controlling the arrival time, thus allowing the carriers to conserve fuel by flying more efficient routes/speeds and still meet GDP objectives. Potential weather integration needs include but are not limited to convective weather, turbulence, in-flight icing, and ceiling and visibility.

2. Environmental Modeling & Analysis of TFM Performance - Fuel Burn Estimation (Metron Aviation, CE Phase): The goal for this research is to develop (using, e.g., POET-R and

NASEIM) methods to compute fuel burn for individual flights. This capability would allow performing analyses that show the impact of various TFM actions on fuel burn. For instance, a reroute might cause NAS users to need to burn additional fuel, and this could be weighed against the benefits of the reroute. In addition to enabling analysis of historical performance from a fuel burn perspective, this would represent a first step towards a fuel burn analysis capability that could be incorporated into decision support tools. Potential weather integration needs include but are not limited to accurate and reliable flight level wind information as well as determination of weather impacted airspace.

<u>3. Reroute Impact Assessment (RRIA) (Metron Aviation, CD Phase):</u> Existing rerouting strategies require the traffic manager to manually identify route alternatives via a process that can be both time-consuming and ineffective at mitigating the underlying capacity constraints. The purpose of the RRIA project is to conduct analysis and rapid prototyping capabilities for evaluating alternative rerouting strategies. Proposed task areas include integration methods for querying the RMT database and functionality from TSD, Reroute Data Analysis to for historical data analysis to enable predictions of which reroute option will be selected, and Graphical Reroute Construction (Reroute Builder) to provide point and click creation of flyable reroutes. Potential weather integration needs include but are not limited to convective weather, turbulence, in-flight icing, flight level winds and ceiling and visibility.

<u>Weather Involvement – Preliminary Review: MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities</u>

An important part of Trajectory Flight Data Management (TFDM) will be the success of the System Wide Information Management (SWIM) program, incorporating the concept of Net-Centricity which was developed by the Department of Defense (DoD) to address data sharing issues. To successfully integrate into the SWIM environment and meet the NextGen vision, the concept of a common flight profile has to be fully deployed.

The flight profile describes a single flight with a compilation of information elements, available for distribution (electronically) and used by both the NAS users and the ANSPs. As the NAS advances with new capabilities, this concept enables the sharing of flight information elements among new and existing functions. Sharing common information elements improves the accuracy and availability of flight information updates, the consistency of flight planning in different ATM system domains, and enhances the availability of user preferences and recorded history information.

In a limited fashion, the concept of a common flight profile is currently available in the future enroute automation system to make data available to various internal components. Interim transition measures are in place for the sharing of enroute flight data information in the near term with other domains once the future enroute system is fielded.

It is expected that the mid-term evolution of the common flight profile managed from pre-departure to post-flight will be adopted across the NAS, offering a single reference for each flight in the NAS. While collaborating with NAS users, TFM trajectory flight data management services will be responsible for instantiating and publishing the common flight profile when the flight plan is filed. Other domains will have access to the flight data elements through publish-subscribe, request-response, and other exchange mechanisms available through SWIM core messaging services. TFM TFDM Services must also subscribe to updates from enroute, terminal, user systems and others in order to continuously monitor for changes that may impact each pre-departure flight and provide feedback to the user. Updates from enroute and terminal TFDM Services may include status such as airspace changes and problem predictions/resolutions (aircraft-to-aircraft, aircraft-to-airspace, aircraft-to-TFM Flow Constraint, Aircraft-to-Severe Weather), and changes in the Terminal Area. A parameter time before departure, control of the active profile will be transferred to the appropriate ATC domain (terminal or enroute) responsible for the departure airport. Each ATM system will have the responsibility to create and maintain specific information elements within the common profile in an operationally acceptable manner.

In TFDM, the aircraft's trajectory is monitored during all phases of the flight. The interaction of that trajectory with other trajectories or hazards will be managed to achieve the optimum system outcome, with minimal deviation from the user-request flight trajectory, whenever possible. During enroute "ownership" of the flight profile as the aircraft progresses through enroute airspace, dynamic information, including 4D trajectories, position, controlling entity, conformance status and security risk elements will be maintained. To improve support for service providers and decision support tools, flight data information provided by the flight deck will be increasingly incorporated into the more precise and complete trajectory modeling. Trajectories will also be shared between terminal and enroute domains, allowing for more consistency and better coordination as aircraft transition between enroute and terminal airspaces. Additionally, data-link capable aircraft will down link dynamic information such as state and weight which will allow for trajectories to be more precisely calculated.

Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap

Weather Integration into Departure Flow Management (DFM)

Departure flow management deals with the efficient movement of aircraft from their gates to the active runway, the timing and sequencing of departures so as maintain runway throughput and overhead aircraft flows (particularly when MIT are in effect). Congestion constraints further downstream are also important in managing departures since it may not be possible to clear aircraft for takeoff if enroute facilities along their route of flight are overloaded.

Considerable effort is underway to develop concepts for integration of weather information into DFM. One needs to consider weather impacts on the departing flights and the flights that are in the overhead stream.

Departing aircraft weather constraints

The prototype Route Availability Planning Tool (RAPT) in operation at New York utilizes CIWS forecasts of storm intensity and height to compute the time intervals where departures from a specific airport will be impacted by storms along specific departure routes. This operational tool incorporates many elements of the weather integration paradigm (frequently updated, automated forecasts of relevant weather parameters, and "translation" of these forecasts into time varying determinations of the availability of a specific NAS resource, in this case a departure route).

Ongoing RAPT work is directed at improving the weather blockage models, developing usable metrics for the uncertainty of the route blockage estimates and extending the concept of operations to less rigid departure route structures than those in use in the NYC airspace where RAPT is being prototyped. There is a need to develop and validate pilot weather avoidance models for terminal areas as well as developing and validating models for terminal airspace usage when impacted by convective weather.

Operational testing of RAPT has illustrated the need for a more integrated departure management process which covers surface movement, rapid reroute planning when the filed route for an aircraft on the surface becomes blocked by weather, integration of overhead stream and downstream sector constraints into the departure planning, and much-improved information exchange involving tower, TRACON and ARTCC controllers and TMs. Weather information requirements for this more integrated departure management process include:

- Nowcasts of airport weather conditions that affect runway usage and airport operations rates (storms, wind shear, wind shifts, winter precipitation, ceiling and visibility changes), in support of proactive replanning of surface operations so as to minimize runway throughput losses and recovery time when major weather changes occur
- Nowcasts of weather conditions (temperature, precipitation rate and type) that affect de-icing holdover time
- Nowcasts of weather conditions that affect gate and ramp operations (lightning, winter precipitation, intense precipitation or hail)
- Accurate gridded wind data and short term forecasts (0-30 minutes) which should extend from the surface to flight level, with horizontal and vertical grid spacing to be established based on analysis of the trajectory modeling requirements, all in support of trajectory planning from the runway through the departure fixes and transition airspace
- Highly reliable wind estimates (effectively measurements) and short-term forecasts (0-20 min) extending from the surface to approximately 1000’ AGL to support wind-dependent wake turbulence departure procedures (see Lang et al., ATM2005) (Note: ongoing wake turbulence research will develop analogous arrival procedures which will facilitate both arrival and departure operations at some airports during appropriate conditions. These require reliable wind estimates to approximately 6000’ AGL and must extend outwards approximately 6 nmi from the airport)
- Forecasts of convective parameters (intensity, height, turbulence) necessary to evaluate departure route availability and to assess the uncertainty associated with these evaluations (Note - the 0-2 hour look-ahead-times provided by CIWS forecasts have proven to be useful for this function although longer forecast horizons would be valuable)

- Diagnoses and forecasts of weather conditions that may change the rate and/or routes at which arrivals can be brought into the airport (Note - examples of such conditions include icing conditions or turbulence in holding areas, or storms blocking major arrival flows to an airport. Operation of the RAPT prototype at New York has shown that when major arrival routes are blocked, the stream of arrivals can deviate into departure airspace which in turn prevents departures from using that airspace [Robinson, DeLaura, Evans and McGettigan, 2008])

A possible vehicle for addressing the above weather factors in improving departure operations is a set of automation-assisted, tower user support tools collectively designated as the Arrival/Departure Management Tool (A/DMT). A/DMT integrates information from a variety of systems (including airport surveillance) and decision support tools to create a comprehensive data base characterizing arrival and departure demand, relevant airport operating parameters and surface/airspace constraints that may affect capacity, efficiency and safety. This data base will be used to develop and manage an integrated plan for active and scheduled arrival and departure operations at the airport, based on 4D trajectory assignments.

In particular, A/DMT will provide decision support for tower controllers working traffic from the enroute environment to the gate, and for departure movements from the gate to the tower/TRACON handoff to enroute control. It will also assist traffic management functions in the tower, TRACON and overlying ARTCC by providing integrated information on constraints and demand.

The vision is that A/DMT will integrate the TFM constraints provided by the Departure Flow Manager (DFM) with weather constraints, wake vortex constraints, runway occupancy constraints, surface congestion constraints and airline constraints to determine the best departure route and associated departure time for each flight. For each aircraft subject to TFM restrictions, DFM would provide a list of departure times for each such aircraft that ensures compliance with the constraints. The A/DMT receives lists of possible departure times from multiple sources [e.g., DFM, Route Analysis and Planning Tool (RAPT), airlines, surface congestion model, etc.], and combines them to determine the set of time windows that each flight can depart to satisfy all constraints. A/DMT provides the window of times for each aircraft for display to the ATCT Controllers. The ATCT Controller selects a departure time from the range in the window, and sends this selected time (and the range of available times) back to DFM in the ARTCC. The communications and displays in the tower would be accomplished by Tower Flight Data Manager (TFDM) which is a new terminal local area network that will establish a highly capable data collection and processing architecture for tower operations. TFDM will consolidate functionality provided today by systems such as Flight Data Input/Output (FDIO), Electronic Flight Strip Transfer System and the Airport Resource Management Tool. TFDM will drive a versatile tower-user display suite consisting of a surface surveillance display, a terminal traffic display, an extended electronic flight strip or "flight data report (FDR)" display, an airport information display and an airport systems status display.

The combination of an upgraded ITWS could provide the wind shear, winds and wind shift information discussed above (albeit the current ITWS surface winds forecast capability is not adequate in terms of lead time for forecasts and the ability to forecast non gust front induced changes). The plan is for the CoSPA to provide both the forecasts of precipitation (including snow) and convective storm impacts.

<u>Overhead traffic weather constraints</u>

If convective weather is present in the terminal area and/or ARTCC, there is a good likelihood that the overhead streams of traffic may also be impacted by convective weather. In particular, when flights deviate around storms such that their flight trajectories no longer correspond to the flight trajectory expected by the DFM software, the DFM computation of flight time from the airport to fit into the overhead stream (or, arrive at a metering fix) will not be accurate. As a result, the departing aircraft might not fit into the expected slot in the overhead stream or at the metering fix. Since the DFM functions that involve departure time adjustments to fit aircraft into the overhead stream are a particular instance of time-based flow management, there will be a need to conduct research on how time-based flow management system can successfully operate in convective weather.

<u>Weather Integration into Time-Based Arrival Flow Management (TMA)</u>

Although neither arrival flow management nor the Traffic Management Advisor (TMA) were addressed in the “CATM Report 2007”, it is logical to consider this function in this roadmap since TMA is in operation at several locations that are frequently impacted by convective weather and hence could be used for experimental testing of concepts.

TMA determines the probable time of arrival of aircraft in enroute airspace to an terminal area arrival fix and then determines how much a plane needs to be sped up or slowed down to yield an appropriate sequence of arrivals over that arrival fix. The desired change in aircraft arrival time to the arrival fix is provided to enroute controllers who then accomplish speed and/or trajectory changes such that the plane passes over the arrival fix at the desired time. The required arrival fix time adjustment is continually updated as the plane proceeds to the arrival fix to provide closed loop control.

The TMA software currently assumes that an aircraft will fly the normal fair weather trajectory. If the plane deviates from the expected flight profile so much that the computed time difference between the desired arrival time at an arrival fix and the current expectation is too large to adjust (especially, when the plane will be quite late in arriving), then the only recourse would be to modify the time sequence of aircraft over the arrival fix. An important feature of the current TMA software is the “freeze horizon” which is typically a range ring from 200 nautical miles to 400 nautical miles around the airport inside which the time sequence of aircraft over an arrival fix is frozen. The time sequences of aircraft over the various arrival fixes are coordinated so as to yield an appropriate sequence of aircraft landing on the various runways assuming the aircraft fly the expected flight profile from the arrival fix to the runway.

It is our understanding that TMA can be operated in some cases where there is limited convective impacts in the enroute airspace of concern to TMA. If the storm impacts are limited to the area near one or more arrival fixes, aircraft scheduled for those fixes which are outside the “freeze horizon” can be transferred to a different arrival fix and TMA will resequence them. If a small number of aircraft deviate around storms such that TMs could accurately estimate the additional flight time to the arrival fix, and determine that there would a suitable arrival fix time slot associated with the extra flight time, then in theory it might be possible to manually resequence the planes. However, if large numbers of aircraft are deviating around storms and it cannot be determined manually what the extra time of flight will be and what sequence order is appropriate, then the current practice is to shut down the operation of TMA and revert to the previous manual control methods.

Research needs to be conducted on methods of making TMA more useful in convective weather. Key elements of the required research include:

- Convective weather events need to be analyzed to determine the fraction of time that convection impacts the region between the “freeze points” and the arrival fixes without also impacting the arrival routes within the TRACON
- If it appears that an operationally useful capability can be achieved by only improving TMA capability when convection is impacting the ARTCC (as opposed to both the ARTCC and terminal), development of a pilot weather avoidance model for descending aircraft in enroute airspace is clearly a first step
- The ability of TMA to consider non standard routings from the principal jet routes to arrival fixes (e.g., routes that might be manually drawn around a FCA using the CATM phase 1 reroute assessment utility) needs to be investigated.

We have recommended manually input routes as opposed to automatically generated routes around storms (e.g. routes generated by algorithms of the type described in Krozel, et. al., 2004) since it appears that the current automatic route generation algorithms do not consider complexity (Histon, et. al., 2002) in determining merge points whereas humans would consider controller complexity.

Extensive testing of various modifications to the TMA software using data sets from the current TMA sites (e.g., ATL, DFW, or IAH) seems essential. Given that NASA Ames was the principal research organization for the development of the TMA algorithms and, has been the principal source of funding to date for development of pilot weather avoidance models, it would seem logical for the FAA to conduct discussions with NASA to determine if Ames would be interested in investigating near-term modifications to the TMA algorithms to provide some enhancement in the ability to use TMA in convective weather.

In parallel, the FAA should utilize existing experienced TMA sites with significant convective weather impacts (e.g., ZTL) as locations to conduct exploratory investigations of how the ATL traffic managers could utilize CIWS weather products (and WAF fields) in determining approaches to extending the ability to use TMA with slight or moderate convective weather impacts. Since the controllers play a key role in the overall operation of TMA (by “closing the feedback loop” to achieve the desired arrival times at arrival fixes, it would be very important for the ZTL areas to have access to the CIWS products (and, additional experimental products that might be developed out of the interaction between TFM weather researchers and the ZTL operational community).

<u>Weather Integration into Integrated Time-Based Flow Management</u>

Integrated Time-Based Flow Management (ITBFM) will provide traffic managers an improved capability to develop, execute and adjust a common and integrated departure-to-arrival schedule for all aircraft that supports both TFM objectives and, to the extent possible, NAS customer preferences. The vision is that this capability will integrate or replace today's separate, uncoordinated and sometimes conflicting time-based metering restrictions (GDP, EDCT, AFP) to provide a more consolidated strategy for NAS resource management. Although ITBFM can be viewed as extension to the time-based flow management concepts embodied in DFM, the need for a departure-to-arrival schedule plan imposes a considerably broader set of requirements relative to weather information. There is a considerable difference between the Metron DFM prototype and TMA to accomplish what appear to be quite similar functions of achieving a desired arrival time at a location (arrival slots or metering fixes for DFM, arrival fix for TMA). The DFM prototype functions essentially as an open loop system that relies on the controllers to manually determine if a flight's trajectory needs to be adjusted to merge into traffic at the desired aircraft in trail spacing whereas the TMA software seeks to arrive at the arrival fix at a specific time.

As a consequence of these differences, there may well be differences in the details of the weather forecast translation into ATC impacts for DFM versus TMA. Hence, it will be important to determine the anticipated mode of operation for ITBFM so as to determine if there are additional weather-to-capacity translation issues that need to be considered in achieving an operationally useful ITBFM. For example, RAPT and the Metron DFM prototype are basically not concerned about forecasting departure rates. Rather, they simply attempt to optimize the departure rate for the sequence of planes that is ready to depart. One might be able from the current RAPT timelines to infer a departure rate for the next 30 minutes. But, such a short duration rate estimate would hardly be helpful for ITBFM and/or GDPs due to convective weather in the terminal area.

A major problem is forecasting arrival or departure rates at an airport an hour or more in advance is that the circumstance where the greatest capacity rate impact is likely to occur is when storms are over or very near the airport (e.g., within 5 nmi). Achieving high accuracy multi-hour forecasts of storms impacts over such a relatively small region for anything other than strong synoptic squall lines is a very difficult challenge.

It may well be that the operational concepts for ITBFM may have to be adjusted to have a much more limited scope of operation (e.g., use of TBFM over relatively short look ahead intervals such as an hour) during convective weather. We recommend that early on in the ITBFM development that there be simulations with representative convective weather data sets so as to address concerns at the outset rather than attempting to add on fixes to a deployed system such as will have to be accomplished with TMA.

A-4.3.2 Provide Full Flight Plan Constraint Evaluation with Feedback

Timely and accurate NAS information allows users to plan and fly routings that meet their objectives. Constraint information that impacts proposed flight routes is incorporated into Air Navigation Service Provider (ANSP) automation, and is available to users for their pre-departure flight planning. Examples of constraint information include special use airspace status, significant meteorological information (SIGMET), infrastructure outages, and significant congestion events.

Needs/Shortfall

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 traffic flow management (TFM) issues are 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.

Operational Concept

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.

Design/Architecture

It is likely that the TFM System (TFMS) infrastructure will serve as the focal point for full flight plan constraint-evaluation and feedback capability prior to activation of the flight. TFMS, as one of its many services, will

- Accept aircraft operator trial plans
- Evaluate those plans for how they would be impacted by NAS system constraints
- Provide the operator with timely, accurate, and complete feedback on relevant system constraints
- Accept early intent and filed flight plans
- Forward such flight plans to the TFMS for trajectory-modeling and resource-demand prediction

Weather Integration Considerations – Infrastructure Roadmap (IR)

Weather needs identified include a de-conflicted common weather picture of enhanced forecasts of convection, turbulence and icing. Improved observations are also needed.

Weather Involvement – Preliminary Review: TFM Concept Engineering Plan

No specific information found.

<u>Weather Involvement – Preliminary Review: MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities</u>

The “Flight Plan Constraint Evaluation and Feedback” capability will allow the NAS user to be a pro-active 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 Traffic Management Initiatives (TMIs), the coordination with the NAS user and the allocation of user requested preferences when possible. Prioritized user-preferences will be used by the Traffic Manager (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 or 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), Area Navigation (RNAV) routes), required aircraft performance characteristics (e.g., Required Navigation Performance (RNP), RNAV requirements), active routes, restrictions (e.g., Letter of Agreements (LOAs), Standard Operating Procedures (SOPs), Special Activity Airspace (SAA)), terminal status information (e.g., airport conditions, runway closures, wind, arrival rates, Runway Visual Range (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, new information and 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 and additional 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 options to:

- 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., concept System Enhancements for Versatile Electronic Negotiation (SEVEN) 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 from the traffic manager to address a given traffic management initiative. 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, general aviation, 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.

Beyond the mid-term (i.e., 2019+), this capability could evolve to allow the NAS user the option to automatically file an evaluated flight plan or to submit a route modification (i.e., amendment) to a filed flight plan based on the feedback received and NAS user pre-defined criteria. In the far-term, this capability may evolve into an automated, interactive flight planning and coordination capability to support the NAS user and ANSP negotiation of trajectories.

<u>Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap</u>

More accurate predictions of NAS resource congestion (enroute sector, airspace flow evaluation area and airport) are a major focus of future Traffic Flow Management concepts. Traffic managers use congestion predictions to establish the type, timing and scope of TMIs. Because of the uncertainty in today's predictions, TMs often implement highly conservative strategies as a hedge against worse-than-forecast conditions.

Uncertainty in future resource congestion arises from both inaccuracies in estimating future demand and from very limited capability to predict the future capacity of NAS resources during adverse weather. Demand predictions today do not even fully account for the impact of currently approved TMIs (for example MIT or arrival fix restrictions), and certainly do not attempt to estimate the impact of future TMIs that may be imposed as new weather constraints develop.

Quantitative, dynamic predictions of resource capacity are not currently available and as a result,

TMs must subjectively estimate the impacts of adverse weather on future airport operations rates and enroute airspace capacity.

In the initial mid-term time frame (2010-2011) CIWS weather forecasts will be integrated with the traffic display to allow TMs to visualize the impact of the weather on major routes, sectors and other airspace volumes. The display of CIWS product information on traffic management displays (as opposed to being provided on separate CIWS displays) will significantly enhance traffic flow decision making in adverse weather because traffic flow and weather information will now be available on a single display. Additionally, this transition will free up display space at crowded facilities and, provide CIWS products to some decision makers that could not easily view the CIWS demonstration system displays due to facility space restrictions. Additionally, TMUs and area managers in ARTCCs west and south of the northeast quadrant of the United States will obtain access to the CIWS products.

CIWS weather forecasts will be integrated with the “future traffic display” to allow TMs to visualize the impact of the weather on the specific flights that are expected to be traveling on major routes, sectors and other airspace volumes. This should assist the TM in determining which flights to move or conversely, when to cancel currently active TMIs that may no longer be needed. Use of more explicit mappings of the weather diagnoses/forecasts into constraint estimates, such as the WAF described previously, would further enhance the operational utility of the future traffic display. Use of the CoSPA forecast should facilitate extension of this concept to longer (0-6 hour) look ahead times in the mid-term time frame (2012-2013).

Probabilistic resource demand predictions must model not only currently approved TMIs but the likely effects of future TMIs that will be needed in response to weather constraints that are worsening or may not yet have developed. To properly model these future flow restrictions, a NAS-wide model accounting for time-varying future resource capacities and total (scheduled and pop-up) demand is needed. Since the skill of the demand and weather constraint predictions will generally improve rapidly for shorter look-ahead times, this model must cycle rapidly (~ twice per hour) in order to take advantage of the improving information on future constraints. Development of such a real time model that fully integrates state-of-the-art weather predictions, weather-impact translations and traffic demand forecasts is a major undertaking that does not appear to be adequately supported in the current weather and TFM research portfolios.

“CATM Report 2007” states that CIWS forecast data will be used in the mid-term time-frame to predict the reduction in expected resource capacity. Further, for each resource and each look-ahead time, the probability distribution function of the capacity will be determined by TFM. The authors speculate that this may be implemented for enroute sectors as a reduction in the Monitor Alert Parameters (MAP), based on the weather coverage, route blockage or other considerations. Realizing a robust capacity prediction capability will require major effort in at least three areas. Continued progress in diagnosing and forecasting relevant weather phenomena over the 0-8 hour time scales needed for TFM is essential. Research may be focused on extending the look-ahead-time for convective weather forecasts to 6-8 hours, and on improved 0-2 hour “nowcasts” of turbulence and airport weather conditions (ceiling and visibility, winds, winter precipitation) that affect capacity.

Validated models for translating the weather information into quantitative resource constraint metrics are required. Research in this area is in its infancy. For airspace constraints, the authors believe that approaches based on algorithms for reduction of sector MAPs are problematic. MAPs are widely recognized to be subjectively determined and inconsistent across the NAS, even during nominal conditions. Scaling of MAPs to account for weather impacts must account for the directionality of major flows within a sector and, that the associated weather blockage that may be quite different for different major flows. Objective models for airspace capacity during both nominal and off-normal conditions are likely to be more useful (e.g., Welch et al., 2007; Martin et al, 2007; Song et al., 2007) but these approaches must be integrated, validated and adapted as necessary to future, more automated ATC paradigms. Augmented research on the impacts of non-convective weather phenomena (turbulence, icing) on airspace capacity is needed, as is a more comprehensive capability for predicting weather impacts on future airport operating rates.

Viable methods for estimating and conveying the uncertainty of future resource capacity predictions must be defined. This will require tightly coupled effort involving the meteorological forecasting and ATM research communities. The authors believe that “ensemble” approaches are most likely to be effective – that is a set of discrete weather forecasts will be developed that span the expected range of future scenarios, and these will be translated individually to associated estimates of capacity constraints on specific NAS resources. From these ensembles, appropriate metrics and visualizations of uncertainty can be transmitted to automated decision support tools and TMs.

A-4.3.3 On-Demand NAS Information

National Airspace System (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.

Needs/Shortfall

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.

Operational Concept

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.

Aircraft & Operator

Operators can choose among an assortment of information services to access the NAS data. Equipment to receive Flight Information Services-Broadcast (FIS-B) will provide access to Special-Use Airspace status and Notice-to-Airmen (NOTAM)-related data over the Universal Access Transceiver (UAT) link. Data communications will provide access to Digital Automated Terminal Information System (ATIS) data. For flight planning, any user can access the NAS information through System-Wide Information Management (SWIM).

Design/Architecture

The SWIM program office will coordinate Communities of Interest (COI) to define producer and consumer requirements for the improved distribution of NAS information. Using standards and technology approved by the SWIM Program Office, COI producers employ approved standards and technologies to develop the services required to publish necessary NAS information. Such information can then be made available quickly and easily, using standard uniform interfaces to

COI consumers. In parallel, COI consumers will develop interfaces to subscribe to provider services that can provide information tailored to user-specified information needs. Due to the loosely coupled nature of SWIM technology, the on-demand NAS information capability will evolve as each producer and consumer completes their individual developments. For those equipped with UAT FIS-B, special use airspace status and NOTAM data will be available. For those equipped with data communications, digital ATIS information will be available.

<u>Weather Integration Considerations – Infrastructure Roadmap (IR)</u>

Deconflicted Common Weather Picture available for TFM and AOC/FOCs

<u>Weather Involvement – Preliminary Review: TFM Concept Engineering Plan</u>

No specific tasks noted.

<u>Weather Involvement – Preliminary Review: MITRE Initial Evolution Analysis for Mid-Term Operations and Capabilities</u>

On-Demand NAS Information (ODNI) will support the need for shared situational awareness between ANSPs and NAS users by supporting the dissemination of consistent and accurate NAS status information in a standard, structured format to ground-based and aircraft-based NAS users. NAS status information is any information concerning the establishment, condition, or change in any component (facility, service, or procedure, hazard, airspace, or route) of the NAS. This is distinct from flight-specific information, which provides information related to a specific flight.

NAS status information may be either static or dynamic in nature. Examples of static information include:

- Airspace structures
- Airway definitions
- NAS facility locations
- Inter-facility letters of agreement, and memorandums of understanding
- Standard procedures
- Special Activity Airspace (SAA) definitions

Static information does not typically require immediate dissemination and is most often used by NAS users to baseline their own information and systems. However, dynamic NAS status information requires timely and reliable dissemination for NAS users to be able to respond appropriately. Some examples of dynamic NAS status information include:

- Congestion predictions
- Planned and active Traffic Management Initiatives (TMIs)
- Current weather constraints and SIGMETs
- SAA usage schedules
- Facility outages and runway closures

- Airspace constraints

The ODNI capability will provide automation which will:

- Collect constituent data from ANSP authoritative data sources.
- Process collected data into NAS Status information in a standardized format.
- Disseminate the information to NAS users in a timely manner via most appropriate means.

Raw data which provides the basis for standard, consistent and usable NAS status information is maintained in systems across the various FAA domains. This information will be collected, stored and processed to create the NAS status information elements to be provided to the NAS user community. Processing of the data will result in standardized, structured machine-readable information formats to support automated information sharing. This information must also be easily transformed for display in human readable format as well, to support dissemination to NAS users who lack the sophisticated automation to receive the machine-readable information.

Standardized information exchange models will be developed and/or adopted, with consensus from appropriate Community(-ies) of Interest (COI), to ensure broad NAS status information interoperability. The Aeronautical Information Exchange Model (AIXM), currently being developed by the FAA and the International Civil Aviation Organization (ICAO), is an example of a candidate information exchange model which will support interoperability standards for NAS status information. Research is required to identify whether other standards may be applicable.

NAS status information will be disseminated to ground-based NAS users in one of two ways, depending on the ability of the NAS users to receive the NAS status information. NAS users that can take advantage of system-to-system information exchange will receive NAS status information via a SWIM-based external service interface. NAS users that do not have the ability to process SWIM-based service interface digital data will be able to access NAS Status information through an improved web capability which will provide rich and dynamic functionality. This improved NAS Status web capability will allow users to maintain login profiles with tailored content and display preferences.

NAS status information will be disseminated to properly equipped aircraft via planned enhancements to data communications which will allow modernized Flight Management Systems (FMSs) to receive and display the status information. Aircraft equipped with Universal Access Transceiver (UAT) Flight Information Services-Broadcast (FIS-B) will have access to Special Use Airspace status and Notice to Airmen (NOTAM) data. For those equipped with Data Communications, digital Automated Terminal Information System (ATIS) information will be available.

Consumers of NAS information, regardless of whether they are systems or direct users, will be able to request subsets of the information to maximize the efficiency of data communications. Information will be made available in both request/response (pull) and publish/subscribe (push) style interchanges.

Although NAS users will be able to access a wide range of information representing the status of the NAS, as understood by various systems used by ANSPs, they will not have access to the same level of detail or, in some cases, all of the types of information which can be accessed by ANSP personnel. Appropriate security and information safeguards will be implemented to ensure that NAS users will only be provided the appropriate level of information in NAS status information feeds or web-pages.

Weather Involvement – Preliminary Review: MIT/LL Weather Integration Roadmap

Sector Demand Prediction

Probabilistic resource demand predictions must model not only currently approved TMIs but the likely effects of future TMIs that will be needed in response to weather constraints that are worsening or may not yet have developed. To properly model these future flow restrictions, a NAS-wide model accounting for time-varying future resource capacities and total (scheduled and pop-up) demand is needed. Since the skill of the demand and weather constraint predictions will generally improve rapidly for shorter look-ahead times, this model must cycle rapidly (~ twice per hour) in order to take advantage of the improving information on future constraints. Development of such a real time model that fully integrates state-of-the-art weather predictions, weather-impact translations and traffic demand forecasts is a major undertaking that does not appear to be adequately supported in the current weather and TFM research portfolios.

Far-term Capabilities

TBD

A-4.4 Additional Initiatives and Targets

Weather Integration Review: TFM Concept Engineering Plan

System Enhancement for Versatile Electronic Negotiation (SEVEN) (Metron Aviation. PD Phase): Rerouting flights can be manually intensive, time and attention-consuming while giving little consideration to NAS customer input. SEVEN provides a concept for managing enroute congestion that allows NAS customers to submit prioritized lists of alternative routing options for their flights. It also 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. SEVEN has the potential to reduce traffic manager workload, while allowing better traffic control in uncertain weather situations. Thus, SEVEN gives NAS customers greater flexibility to operate their flights according to their business priorities.

Input from MIT/LL Weather Integration Roadmap

During the mid- to late WP2 time frame (2012-2015) it assumed that the NAS customer will be able to submit to TFM multiple, priority-ordered flight plan alternatives for each flight during both pre-departure planning and airborne flight phases. It is assumed that the customer will determine the selected alternatives and their priorities based on information from TFM describing the location and probability of congestion that aircraft are expected to encounter based on their early-intent flight plan. The customer, will in fact, be able to use this information to “distribute” the expected impact of TMIs amongst their affected flights so as to minimize the overall disruption to their operations. For example, delay on “critical” flights could be traded off to other less critical flights. The “System Enhancements for Versatile Electronic Negotiation (SEVEN)” concept under development by Metron Corporation can be viewed as a prototype for this capability.

The TFM system would be able to choose between the various flight plans prior to take off and then modify the routing later in the flight when shorter lead time and more accurate information was available.

Traffic managers can assess the impact of various flight plan options on system congestion using an Interactive Dynamic Flight Lists (IDFL) and choose an option from the customer submitted list that provides weather avoidance and meets airspace capacity constraints. Changes to the filed flight plan are executed automatically and does not require coordination with the customer nor other facilities.

The utility of this concept when it is used to mitigate weather impacts on NAS customers will vary substantially from case to case, depending on the skill of the weather forecasts (which is a function of the type of weather and the look-ahead-time needed), the ability to accurately estimate NAS resource constraints from these forecasts, and the sophistication of the customer’s process for utilizing this information to define and prioritize alternatives for the impacted aircraft. At minimum, we believe that the TFM weather information system supporting this concept should provide the following capabilities.

The phenomenology and severity of the predicted weather constraint should be identified (e.g. convection, turbulence, ceiling/visibility or runway winds limitations at an airport).

The observing and/or forecast systems used to determine the constraint should be identified, and the “raw” meteorological observations/forecasts provided by these systems should be available as an optional source of information for the NAS customer. This provides customers the ability to potentially improve their operational processes through use of private-sector aviation weather forecasting services.

Quantitative, time-varying forecasts of the reduction in NAS resource availability due to the weather should be provided. Appropriate metrics may are discussed in section 4. Useable estimates of the uncertainty in NAS resource availability should be provided.

There are a number of subject areas that have been identified, which are possible candidates for weather integration, these topic required further review as the plan is refined and evolves; these include the following areas and domains:

- • Increase Safety, Security and Environmental Performance (SSE)
- • Transform Facilities (Facilities)
- • JPDO Working Group Initiatives
- • AJN Initiatives
- • DOD Considerations

- DOD Methodologies for Weather Integration into ATM Decisions
- Operation of Civil Aircraft in Military Controlled Airspace and Terminals
- Transitions Between Civil and Military Airspace
- Air Carrier Considerations
- GA Considerations
- High-End GA
- Low-End GA
- HEMS
- Commercial Space Transportation Operational Activities