Joint Planning and Development Office

# NextGen Avionics Roadmap

Version 1.2

September 21, 2010

Next Generation Air Transportation System
Joint Planning and Development Office

| Report Documentation Page | | | | | *Form Approved OMB No. 0704-0188* | |
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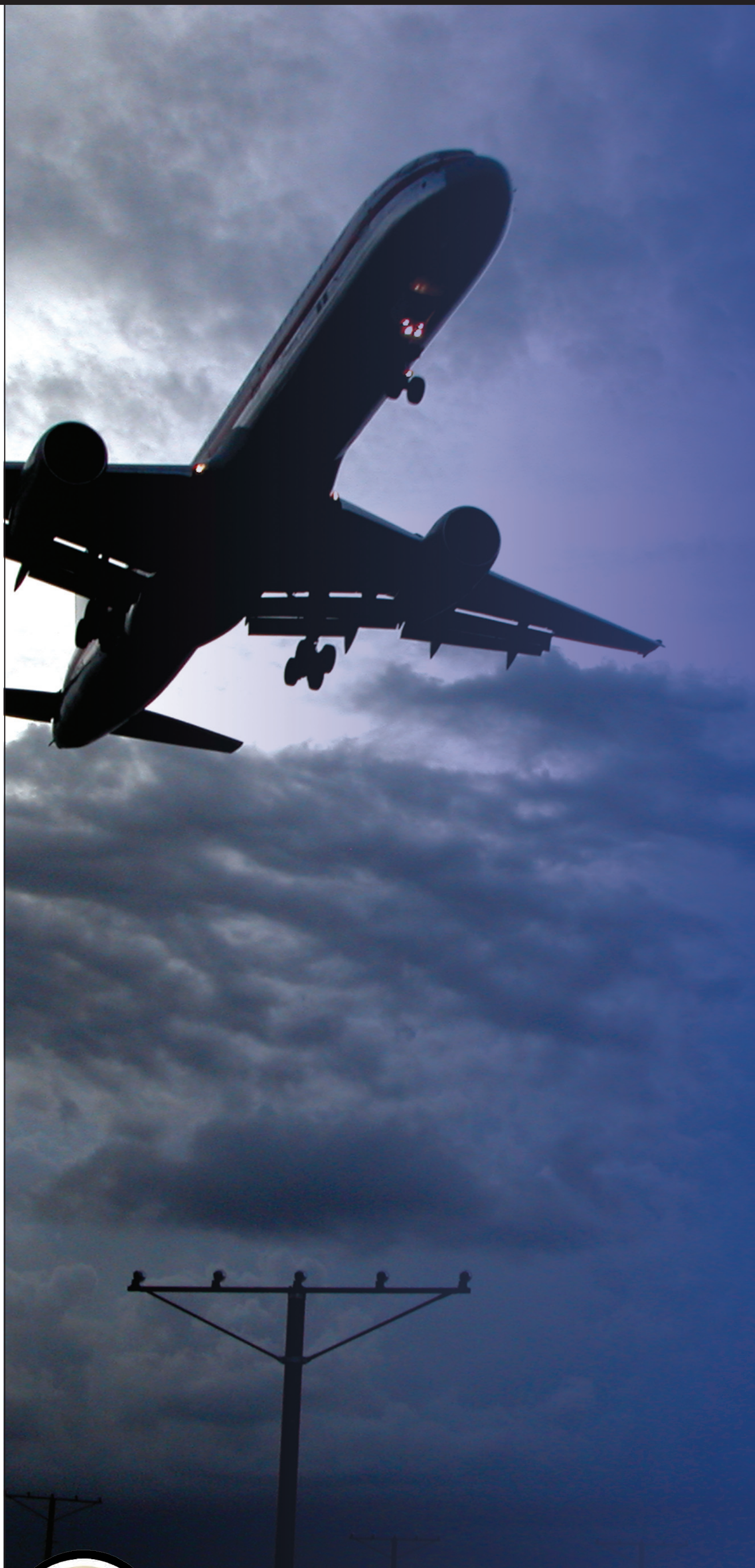

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## Purpose and Background

The purpose of the Next Generation (NextGen) Air Transportation System Avionics Roadmap (ARM) is to translate proposed NextGen improvements into aircraft-related capabilities and functions. This roadmap was developed by the Joint Planning and Development Office (JPDO) Aircraft Working Group. It is intended to provide other organizations involved in NextGen planning with an initial **aircraft-centric perspective** to assist them in understanding the integration necessary between principal components of National Airspace System (NAS) development—air traffic technology and procedures, communication, surveillance, and flight planning systems. Stakeholders will benefit from reading this document because it will provide them with an initial view of the avionics-related capabilities required for the different types of operations envisioned for NextGen. The primary focus of this roadmap is improved air carrier and air transport operations through 2018 (NextGen mid-term), with some work presented that broaches the far-term time frame 2019 and beyond. The scope of this work will be expanded in 2010.

The overall vision of NextGen was created to address ways to safely expand the current National Airspace Infrastructure to support the projected growth of air travel in the United States while continuing to maintain high safety standards, provide greater efficiency and predictability of operations, and do so in an environmentally friendly manner. This roadmap supports these broad NextGen objectives by identifying the role of aircraft in enabling these preferred operations, principally through advanced avionics systems.

Material for this roadmap has been drawn almost entirely from existing sources that have captured different aspects of how aircraft operations are expected to change through utilization of improved avionics. These sources include the JPDO NextGen Concept of Operations (ConOps), JPDO NextGen Integrated Work Plan (IWP), and the Federal Aviation Administration (FAA) NextGen Implementation Plan (NGIP—formerly Operational Evolution Partnership). Other source material comes from existing and draft FAA advisory material, Radio Technical Commission for Aeronautics (RTCA) Special Committee Reports, and the FAA's Performance Based Aviation Rulemaking Committee (PARC). This document is aimed at bringing these different proposed changes together into one perspective so the aviation community as a whole can better understand the key avionics system evolutionary changes expected for NextGen, gaps that have been identified, and plans to address them.

This roadmap does not represent a complete picture of how NextGen will be executed; rather, it focuses on the aircraft component in recognition that the aircraft will be a key integrator for NextGen. This roadmap will mature over time and is expected to be incorporated into other NextGen planning documents as they are revised.

This roadmap is also intended as a continuing step to help focus the discussion and debate needed to grow consensus in the aviation community, and a way to facilitate subsequent NextGen planning as it relates to improved aircraft capabilities and corresponding avionics.

## Aviation System Context

There are a number of challenges that must be addressed in the development of avionics to achieve the capabilities identified for NextGen. The basic challenges are system oriented and involve increasing system capacity while maintaining efficiency, advancing safety, and ensuring a positive cost/benefit ratio for NextGen investments. The aviation fleet operating in the United States is very diverse, including both domestic and international users operating large air transport aircraft, military aircraft, light piston- and jet-powered business aircraft, tiltrotors, helicopters, airships, gliders, Unmanned Aircraft Systems (UAS), and more.

### System Capacity and Efficiency

According to FAA and industry estimates, passenger growth over the next 17 years is expected to increase 73% with operations increasing by 41%. Limited runway construction is projected during the mid-term time period beyond that at Chicago O'Hare, which is expected to be completed in 2013. Environmental concerns will also impact airport expansion, constraining capacity even further.

NextGen avionics, advancements in air traffic automation systems, and modifications to existing air traffic policies and procedures will provide solutions to mitigate these conditions. More specifically, improvements to the overall operation of the NAS will be achieved by deconflicting traffic flows in dense terminal areas and enabling routing that meets the environmental concerns of the communities served by the airport, while efficiently accommodating growing en-route traffic.

Advances in NextGen avionics and Air Traffic Control (ATC) automation and procedures may also enable the system to safely maintain capacity in spite of convective weather en route and reduced visibility in terminal areas, which today cause 78% of delays. Allowing aircraft to operate in instrument conditions as they would in visual conditions will eliminate a substantial percentage of those delays. Finally, Trajectory-Based Operations (TBO) will enable additional efficiencies, and can be tailored to meet a given airspace need or operator capability. Automatic Dependent Surveillance – Broadcast (ADS-B) Out and ADS-B In capabilities will allow greater throughput at non-radar, non-towered airports, increasing safety and efficiencies for general aviation (GA) operators at remote locations.

### Cost and Benefit Considerations

Costs to an aircraft operator, whether airline or military come in two forms -- capital and operating. Capital costs reflect the expenses incurred when purchasing the aircraft or implementing major upgrades. Operating costs reflect the costs of operating the aircraft, including such factors as fuel, labor, maintenance, etc. When considering avionics purchases, a large part of the justification is dependent upon the services provided that allow the avionics to be used to its full advantage. Operators will not invest in new avionics where there are no services to support them or in the absence of a clear business case. Avionics equipage decisions for GA do not depend on cost/benefit analysis in the same way they do for commercial operators. Some GA operators may be unable to make the investment in upgrades that constitute a significant percentage of the aircraft hull value and cannot be recovered in the resale marketplace. Others may choose to install all the latest avionics capabilities regardless of a quantifiable return on investment. This is a very important factor that must be considered in the overall planning and implementation of NextGen and amplifies the importance of integrating the aircraft capabilities, the air navigation service provider (ANSP) capabilities, and the user needs to come up with the best overall solutions for NextGen.

Operating costs are greatly influenced by the efficiency of the NAS. Enhanced services can significantly improve the benefit ratio for both normal and non-normal operations (as affected by adverse weather conditions). One of the key elements in NextGen will be the application of TBO that will allow commercial operators to have greater predictability for their operations, reducing flight times and thus block times. This allows operators to improve their schedule reliability and lower block time costs, resulting in a better product for their customers at a lower unit cost. Non-commercial operators who equip appropriately will also benefit because it will improve access either to or through high-density terminal areas, resulting in reduced fuel requirements and thus lower costs. The use of TBO will also allow all operators to tailor their avionics to meet their particular mission requirements.

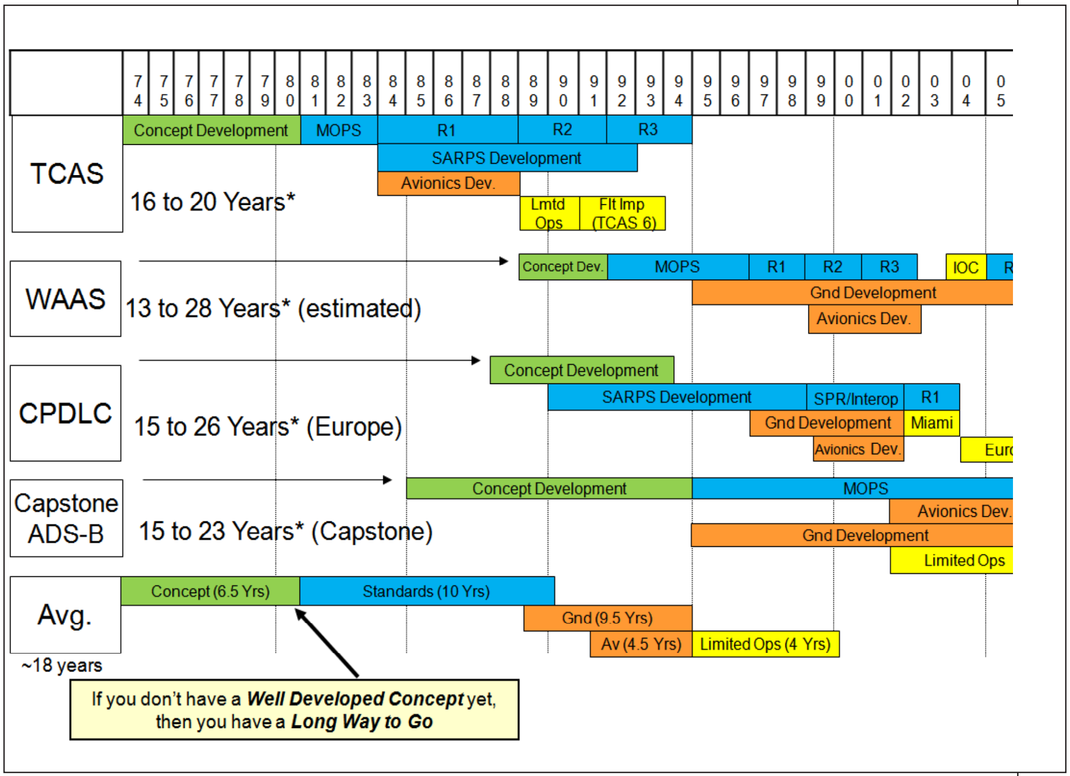
A key factor that will influence the cost/benefit ratio is the issue of retrofitting older aircraft with NextGen avionics. Retrofit will not only apply to existing legacy aircraft, but to today's new aircraft, as well. Aircraft such as the Boeing 787, Airbus A350, and GA purchased near-term will not be delivered with NextGen avionics because a portion of the capability envisioned for NextGen may not be available until late in the mid-term or perhaps early into the far-term (2019 and beyond). This emphasizes the importance of finalizing NextGen avionics requirements as soon as practicable to allow the appropriate amount of time for development, certification, and implementation. NextGen avionics must be developed within retrofitting constraints, including avionics weight, power consumption, antenna space, antenna cable paths, panel space, and conventional form factor. These are issues for many aircraft, and especially the legacy GA fleet. Size, weight, and power consumption will remain issues even for forward-fit of new low-end GA aircraft.

New technologies can be phased in gradually while maintaining infrastructure for the technologies they are replacing. It should also be remembered that both avionics and Air Traffic Management (ATM) system demands will continue to evolve past our present definition and expectation of NextGen, so that even a fully NextGen-capable aircraft will quickly become a legacy aircraft once future ATM system upgrade initiatives are undertaken. Incentives to equip should include commitments to provide continuing benefits from that equipage over sufficient time for the operator to recoup the investment.

As noted previously, the Avionics Roadmap is aimed at bringing together many sources of information to enable a broader understanding of the capabilities aircraft need for NextGen. In time, the implications of those capabilities (cost, benefit, risk, availability, relationship to later changes, etc.) will need to be clearly understood, as all of these factors must be considered together to make the best decisions for NextGen. This contextual information is considered critical to enabling the overall dialogue, debate, and decisions needed for NextGen. To support issuance of the first version of the roadmap, an initial assessment of benefits and risks was conducted for each of the proposed aircraft capabilities. This is valuable work and will be used to guide the next steps in maturing the Avionics Roadmap.

## System Safety – Avionics Constraints: *Historical* Communication Navigation and Surveillance (CNS) Lead-Times

From an avionics perspective, safety is the primary factor that drives the design, development, and approval process to ensure the new functions/capabilities meet the appropriate level of integrity. This applies to both the hardware and software designs. This process then carries over into the integration of the avionics with the airframe. The safety implications associated with the capabilities presented in this roadmap will be addressed in future updates. In recognition of the work that lies ahead in terms of solidifying specific changes needed for NextGen, it is important to highlight that many past efforts involving avionics system upgrades have spanned long periods (15-25 years with an average of 18 Years - as shown in the figure below). For NextGen to be successful, all stakeholders will need to work more collaboratively and at an accelerated pace to enable these important improvements to be utilized in shorter time frames. Procedures and system designs must be failure tolerant and not drive equipage beyond what is required for safety. Examining the safety issues associated with proposed changes up front will be important in minimizing the associated timelines for development and implementation.



## Call to Action

The National Air Transportation System faces four challenges that are key tenets of NextGen:

- o Coping with increased demand for air transportation
- o Improving current levels of safety and security, commensurate with increased operations
- o Minimizing environmental impacts and
- o Ensuring that the overall changes to the NAS are economically viable

One of the most significant challenges in implementing NextGen is ensuring that the operational improvements and capabilities are properly distributed between the aircraft, air traffic system automation, and operator flight planning systems. Integration of these elements is critical not only to the future system's operation, but also to properly distributing the required capital investments of the participants. This version of the roadmap provides an aircraft perspective on how capabilities and functionality can be allocated between multiple sources, primarily through the mid-term (2018) time frame.

This document is provided with the objective of broadening the dialogue, debate, and decisions needed to advance NextGen. This is enabled through:

- o Illustrating, from the aircraft perspective, the expected evolution in NextGen operations. Initial focus is on air transport operations through the mid-term.
- o Proposing an approach for aircraft participation in TBO (at an applications level) in consideration of using both commercial communication services such as System-Wide Information Management (SWIM) and certified data link capabilities, and the limitations of each. It is recognized that this is an aircraft perspective; engagement with the Air Navigation Service (ANS) community and the flight planning functions of the airlines is needed to develop a more complete depiction of TBO operations.
- o Identifying the equipment that enables future NextGen operational capabilities and its current level of maturity.
- o Showing the relationship between several different planning activities that have identified expected avionics system changes. Illustrations are provided that show how these ideas relate to one another and how they support the overall aircraft capabilities envisioned for NextGen.
- o Recognizing that the needs and operations of all users will not be the same. As a result, NextGen investments must be managed to ensure that changes provide realizable benefits to the operator(s) and the NAS. This enables an overall aircraft capabilities framework to be developed without assuming a "one size fits all" solution.
- o Understanding that any aircraft change anticipated for NextGen must be based upon global interoperability to the maximum extent possible. Regional differences must be minimized. This is expected to be achieved through international harmonization, including Single European Sky ATM Reasearch (SESAR) and International Civil Aviation Organization (ICAO). Development of this version of the roadmap has been supported by select experts from the European aviation community. This roadmap provides a point of reference for more in-depth considerations of NextGen and SESAR integration implications.

Collectively, the capabilities presented in this roadmap address the four key challenges noted above through improved operations that enable better use of airspace, enable great operator and controller efficiency, and are more environmentally responsible.

The roadmap shows the planned aircraft capabilities through the mid-term with some indication of the far-term.

## Answering the Call

NextGen is an overall transformation of the NAS, and therefore it is imperative that all users understand the major changes envisioned for this transformation and engage in the overall process of making sure the right changes are pursued and, in time, implemented.

Aircraft operators will play a decisive role in shaping the changes needed for NextGen through focused investment decisions that examine operational capabilities, equipment that enables those operations, the cost of investments, and the return (benefits) from those investments. Those targeted investments encompass new operational capabilities, along with the avionics, procedures, and training that enable them.

To help the aviation community prepare for making these future decisions—*answering the call*—this Avionics Roadmap identifies six groups of operational capabilities important to NextGen. These capabilities are derived from the many proposed avionics system changes that have been captured in different planning activities (JPDO ConOps, IWP, FAA NGIP, and the FAA's Roadmap for Performance Based Navigation (PBN)).

Some proposed aircraft-enabled improvements captured in the JPDO IWP have been deferred from this version of the roadmap, and these are identified and explained. Finally, this roadmap summarizes the initial benefits and risk assessment work completed. This initial assessment is being used to guide the future maturation of the Avionics Roadmap and how the Aircraft Working Group engages with other groups—both inside and outside the JPDO—that are involved in work related to developing these capabilities. Supporting details on each of these aspects of *answering the call* are presented in the appendices to this document.

The following points are noted as particularly important to how stakeholders can help in answering the call to further the overall NextGen planning process.

- Provide comment on the usefulness of this roadmap and what your community needs for it to be a fully mature source of information. It is recognized that industry and government stakeholders need additional information regarding functional allocation, detail performance requirements, and equipment requirements to facilitate future avionics system planning. In support of obtaining feedback on the roadmap, the JPDO will reach out to various working groups, committees, and associations. The JPDO will also consider holding a workshop to reach other stakeholders and solicit input on ways to improve this product, including how to integrate the needs of different user communities (GA, military, Unmanned Aircraft Systems (UAS), etc.).
- Identify how this roadmap should be used to revise other NextGen planning documents.
- Specifically review the material presented in Appendix 1 regarding aircraft participation in TBO, recognizing this is a first proposal and that other perspectives (ANS, flight planning) will need to be examined and used to shape a more complete explanation.

## Avionics-Enabled NextGen Operational Capabilities

The avionics-enabled improvements in this roadmap are presented in six groups of related operational capabilities. This approach is intended to identify the type of aircraft operational capabilities that are considered necessary or advantageous for NextGen operations. The objective is to help operators identify the types of capabilities that will be available and likely important to their future NextGen operations, and to show the relationships between the capabilities and the specific changes reflected in other planning documents. The capabilities structure may be incorporated into other JPDO-developed planning documents when they are revised, and this may necessitate minor adjustments to structure depicted in this roadmap.

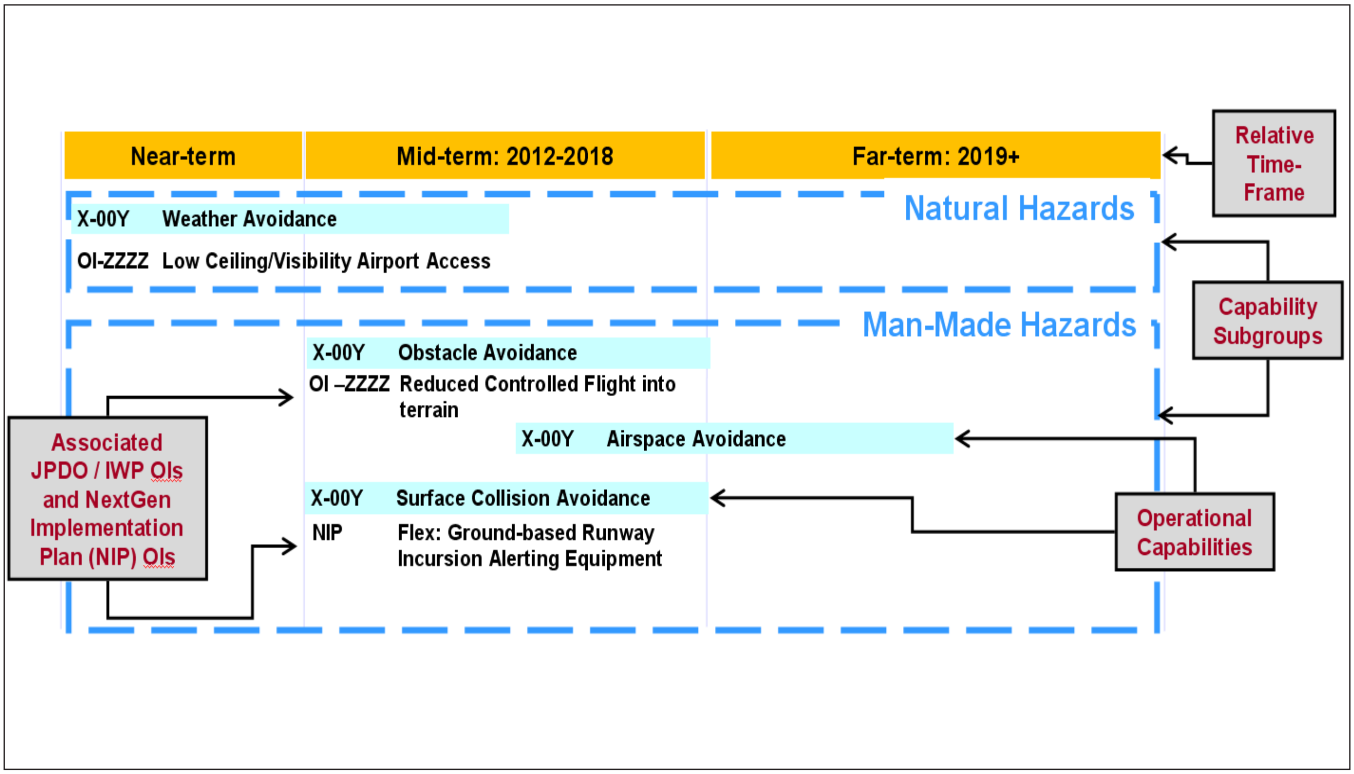
The six capabilities were structured in a building block fashion where capabilities are progressively more encompassing, and therefore enable more complex types of operations. The bullets below provide a high-level snapshot of how the capabilities were structured and relate to one another.

- **Safety Enhancements** – Addresses the fact that NextGen is based upon higher-density operations in the air and on the ground. To support these operations, which are enabled by the other five capability groups, enhancements to existing safety functions will be needed along with consideration of implementing additional safety functions.

- **Published Routes and Procedures** – Predicated on improved operations associated with precision navigation capability—Area Navigation (RNAV) and Required Navigation Performance (RNP).
- **Negotiated Trajectories** – Builds upon the capabilities of precision navigation by adding data communication capability to enable dynamic negotiation of preferred routes.
- **Delegated Separation** – Adds to the capability of negotiated trajectories through the availability of enhanced situational awareness—in the air and on the ground—to enable delegated separation practices to be broadened from use in visual conditions today to use in non-visual conditions in controlled airspace.
- **Low Visibility Approach/Departure and Taxi** – Recognizes that additional aircraft capability is available today to enable operations in weather-limiting conditions and with less dependence on costly ground infrastructure. This allows operations to more readily adapt to changing situations without reliance on existing or new ground infrastructure.
- **ATM Efficiencies** – Identifies capabilities that improve the ATM process, thereby reducing the FAA's costs of operations and/or enabling new services to be provided.

The six groups of capabilities outlined above are fully aligned with the FAA's NextGen Implementation Plan published in June 2008. This is critical from the standpoint that the Avionics Roadmap is aimed at addressing the overall evolution of aircraft capabilities and how they are enabled by certain avionics. To do this, there must be a clear understanding of what is in place today, what is committed, what is coming (per the NextGen Implementation Plan), and what needs to be added in the far-term to fully utilize these broad capabilities.

For each of the six capability groups, a separate chart depicts near-term/mid-term/far-term timeframes along with expected initial availability of each operational capability (uncertainty may span more than one timeframe). Below the operational capabilities timeframes are the operational improvements (OIs) that support that capability from the JPDO IWP, the NIP, and the Performance Based Navigation (PBN) Roadmap. Using this approach, the complexity of the expected change for NextGen can be simplified by showing the relationship of individual changes that have been identified and how in many cases they are aiming to depict the same higher level capability. Interpretation of these charts is illustrated here:



Adjacent to each chart are descriptions of the operational capabilities with a list of key avionics enablers. The key avionics enablers may have options within the given set. The maturity and operational readiness of these enablers is color/font coded. **Green Bold Enablers** are mature for use in supporting that capability. Orange Underlined Enablers, although specifically known, are not yet completely standardized, implemented, certified, or approved for use in that capability. *Italicized Enablers* require additional understanding as to the specific version of the enabler needed (even if the versions are themselves mature). Appendix 2 provides a tabulation of the enablers and identifies what capabilities are supported by them. This allows the user community to start gaining a sense of the numbers and types of enablers that may be necessary to support operations that will be integral to NextGen.

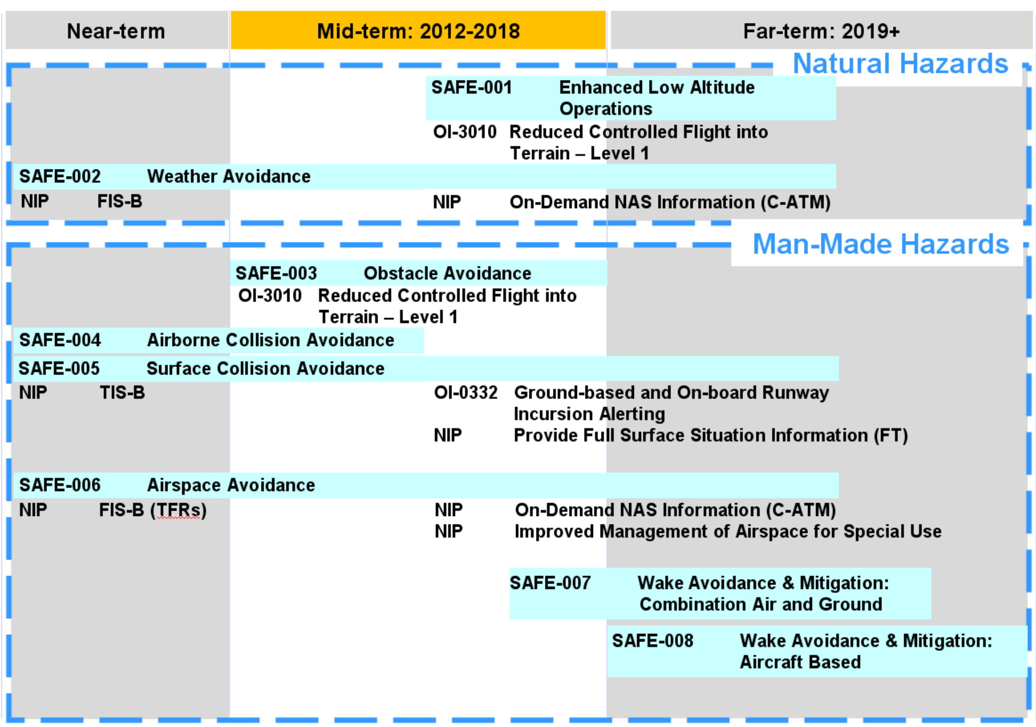
Historical lead-in times for CNS initiatives (15 to 25 years) are dominated by the concept and standards phases of development, which are typically performed in series. A concerted effort to either parallelize these steps or to shorten them to some extent is required, and should be undertaken as part of the JPDO process.

A number of the mid-term capabilities require policy decisions be made in order for the capability to be realized. Virtually all capabilities require that decisions be made about which equipage strategy will be employed. Those strategies will likely differ between capabilities. Additionally, there is a need to set policies to achieve the desired balance between ground infrastructure and avionics equipage. Research and development efforts will sometimes yield multiple solutions for achieving a capability and permit trade space between ground infrastructure and avionics equipage. In an effort to avoid costs, the ANSP and operators will likely favor solutions that shift costs away from them. These policies will need to be integrated with equipage policies. Appendix 5 provides a summary of the JPDO IWP policy issues associated with the capabilities presented in this roadmap. Further refinement of policy issues will be needed as the capabilities, for both mid- and far-term timeframes, are fully matured.

## Safety Enhancement/Hazard Avoidance & Mitigation

Safety enhancements are based on the awareness, avoidance, and mitigation of natural and man-made hazards. Hazards include terrain, obstacles, other aircraft (either on the airport surface or airborne), Special Use Airspace (SUA), dynamic terminal airspace, weather, and wake turbulence. The aircraft continues to play a paramount role in aircraft safety, using flight deck displays of the airport surface, other aircraft positions, and improved hazard information provided by ground systems and other aircraft.

Safety enhancements are key to fully exploiting the potential of the other capabilities presented in the roadmap. In other words, these capabilities and their corresponding enablers will allow a greater potential of the other five capability groups to be achieved. Safety enhancement capabilities also address areas of operation that are considered to have greater vulnerability from a safety standpoint due to higher traffic volumes and different operational procedures expected with NextGen.

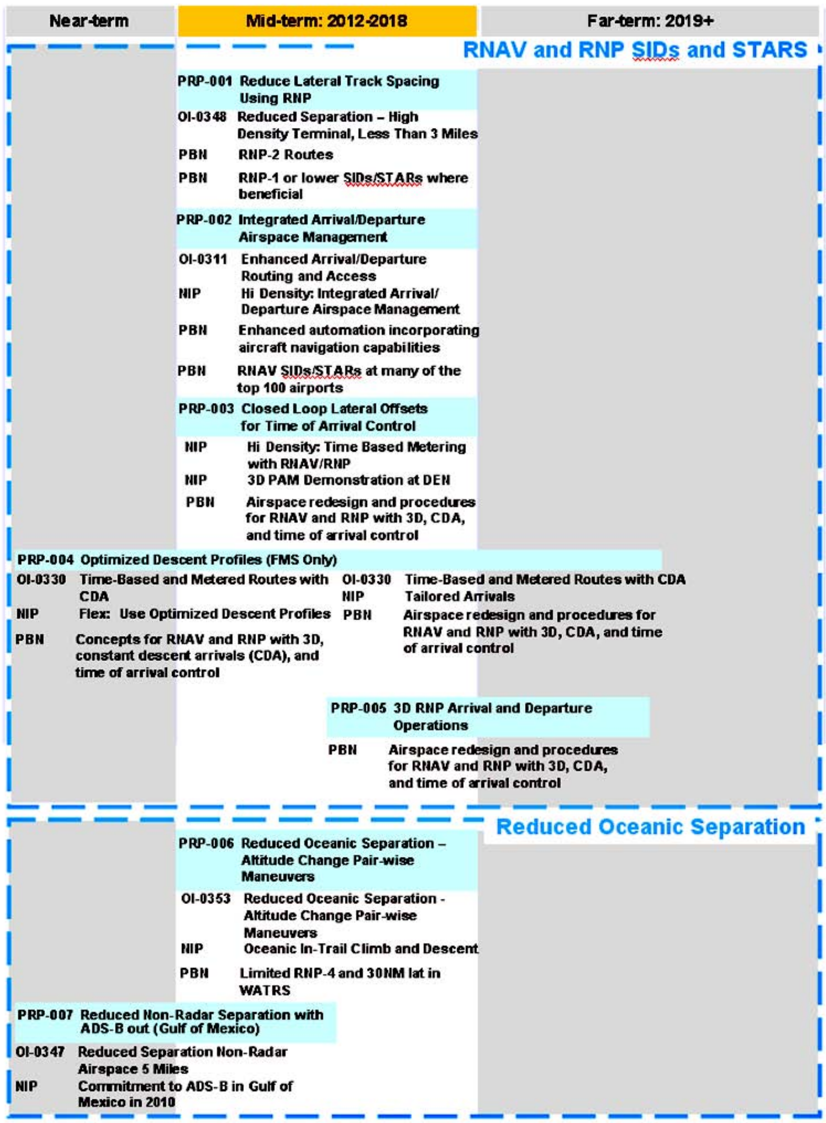


| Capability | Key Enablers |
|---|---|
| **SAFE-001: Enhanced Low Altitude Operations** – Leverage enhancements to Terrain Awareness and Warning System (TAWS) along with higher integrity and resolution terrain databases to reduce Controlled Flight into Terrain (CFIT). ADS-B increases surveillance areas beyond today's radar footprint. | RNP (as required by specific procedure), *Improved Terrain Database, TAWS Enhancements, ADS-B Out* |
| **SAFE-002: Weather Avoidance** – Reduce impact of hazardous weather through broadcast of text and graphical weather information to aircraft. | Flight Information Services – Broadcast (FIS-B), Moving Map |
| Reduce impact of hazardous weather through data link of enhanced weather and turbulence forecasts to aircraft. | FIS-B, Moving Map, and for text only weather information: Initial Data Link (Future Air Navigation System (FANS) 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer )<br>For text and graphical weather information: *Data Link (Not supported by initial data link enablers)* |
| **SAFE-003: Obstacle Avoidance** – CFIT is further reduced through availability of higher-frequency updates related to the position of temporary and permanent (fixed) man-made obstacles. | Improved Terrain Database, Improved Obstacle Database, *Moving Map* |
| **SAFE-004: Airborne Collision Avoidance** – Risk of airborne collisions is reduced through enhancements to Traffic Collision Avoidance System (TCAS) to reduce false alerts in complex maneuvers. | *ADS-B In, Traffic Information Services-Broadcast (TIS-B), TCAS Enhancements* |
| **SAFE-005: Surface Collision Avoidance** – Surface Moving Maps with own-ship and traffic are used to reduce runway incursions. | ADS-B In, TIS-B, Moving Map, Cockpit Display of Traffic Information (CDTI). |
| Surface Moving Maps with own-ship, traffic, and alerting are used to reduce runway incursions. | ADS-B In, Moving Map, *CDTI with Alerting (ground operations).* |
| **SAFE-006: Airspace Avoidance** – Broadcast data link communications is used to provide pilots with updated information on Temporary FLight Restrictions (TFRs), improving pilot situational awareness. | FIS-B |
| Data link communications is used to provide pilots with updated information on TFRs and SUA status, improving pilot situational awareness. | FIS-B, Initial Data Link (FANS 1/A+, FANS 2/B, Aeronautical Telecommunication Network (ATN) Baseline 1 LINK Post Pioneer) |
| **SAFE-007: Wake Avoidance and Mitigation – Air/ Ground Combination** – Pilot situational awareness of wake vortices is improved through communication of ground-based wake detection and prediction information. | Global Navigation Satellite System (GNSS), ADS-B Out, *Aircraft Characteristic Database, Aircraft Wake Database, Wake Transport Model, Wake Decay Model, Data Link (Not supported by initial data link enablers)* |
| **SAFE-008: Wake Avoidance and Mitigation – Aircraft-Based** – Aircraft-based wake vortex sensors are leveraged to further improve detection and prediction, reducing wake hazards in high-density operations. | GNSS, *Aircraft Characteristic Database, Aircraft Wake Database, Wake Transport Model, Wake Decay Model.* |

## Published Routes and Procedures

Because of the large number of aircraft that are already equipped for RNAV and RNP operations, most near-term initiatives involve published routes and procedures. This includes Q-routes, T-routes, RNAV arrival and departure procedures, RNAV (RNP) approaches, and RNAV instrument approach procedures, many with both lateral navigation (LNAV) and vertical navigation (VNAV), as well as localizer performance with vertical guidance (LPV) minima. To take full advantage of existing aircraft capability, additional criteria for published routes are being developed to enable curved-path procedures as part of a departure, arrival, or initial approach. Other criteria being developed will take advantage of VNAV capability on arrivals and departures, using window constraints along a procedure to de-conflict published routes using a 2½-D trajectory.

The capabilities presented below are fully aligned with the FAA Roadmap for PBN, published July 2006. To date, no additional capabilities in the area of Routes and Procedures have been identified from those contained in the PBN Roadmap.



| Capability | Key Enablers |
|---|---|
| **PRP-001 Reduce Lateral Track Spacing Using RNP** – Growing number of RNP-capable aircraft allow the design of en route and terminal procedures with reduced track-to-track separation. | RNP (as required by procedure), RNP Special Aircraft and Aircrew Authorization Required (SAAAR), Radius to Fix (RF) Leg (as required by procedure). |
| **PRP-002: Integrated Arrival/Departure Airspace Management** – Terminal airspace volumes are redesigned and in some cases expanded. RNAV procedures are designed to provide de-conflicted access to and from all airports in busy metropolitan areas. | RNAV |
| **PRP-003: Closed Loop Parallel Offsets for Time of Arrival Control** – Closed-loop parallel offsets from RNAV or RNP Standard Instrument Departures (SIDs) and Standard Terminal Arrival Routes (STARs) provide additional flexibility for metering, merging, and spacing operations. | RNAV, RNP (as required by procedure) |
| **PRP-004: Optimized Profile Descents (OPD) (FMS only)** – Additional procedures are designed that allow minimally equipped aircraft to fly OPDs with minimal impact on terminal areas capacity. | RNP (as required by procedure), VNAV |
| Additional procedures are designed that allow VNAV capable aircraft to fly OPDs with minimal impact on terminal areas capacity. | RNP (as required by procedure), VNAV, *Data Link (integrated with FMS or stand-alone navigator, and not supported by Initial Data Link enablers)* |
| **PRP-005: 3D RNP Arrival and Departure Operations** – RNP-based VNAV capability allows the design of 3D RNP procedures which permit vertical de-confliction of arrival and departure flows, including OPDs. | RNP (as required by procedure), VNAV, *Vertically guided RNP, Data Link (integrated with FMS or stand-alone navigator, and not supported by Initial Data Link enablers)* |
| **PRP-006: Reduced Oceanic Separation – Altitude Change Pair-wise Maneuvers** – Pair-wise separation requirements for altitude changes in oceanic airspace are reduced for RNP-4 and FANS 1/A capable aircraft. | RNP–4, ADS-C, ADS-B, Cockpit Display of Traffic Information (CDTI), FIS-B, Initial Data Link (FANS 1/A) |
| **PRP-007: Reduced Non-Radar Separation** Gulf of Mexico (GOMEX) is the next non-radar area slated for ADS-B operations. In addition to improving enroute operations like Gulf of Mexico (GOMEX), ADS-B Out or Wide Area Multilateration can reduce the "one-in, one-out" restriction now in place on many airports where there is no radar. | ADS-B Out, Wide Area Multilateration |
| **PRP-008: Simplified RNP capability** – Low-performance (low-speed) GA aircraft and pilots can fly RNP 0.3 procedures manually. This item explores minimum equipage for these procedures in Category A and B aircraft (predominately GA). | RNP 0.3 |

## Negotiated Trajectories

By integrating the aircraft's navigation capability with data link, the precision and reliability of RNP routes can be applied to dynamically-defined routes. Many current aircraft have some capability (e.g., FANS-1A) to negotiate a trajectory. Some GA operators may negotiate using conventional voice communications. A negotiated trajectory may be as simple as an expected path from top-of-descent, or as complex as a four-dimensional (4D) path with performance requirements. Negotiated routes may be im-

plemented as 2D trajectories, 3D trajectories, 3D trajectories with a Required Time of Arrival (RTA) at a particular fix (3½-D trajectory), or ultimately, a full 4D trajectory (4DT), including time constraints along the entire trajectory.

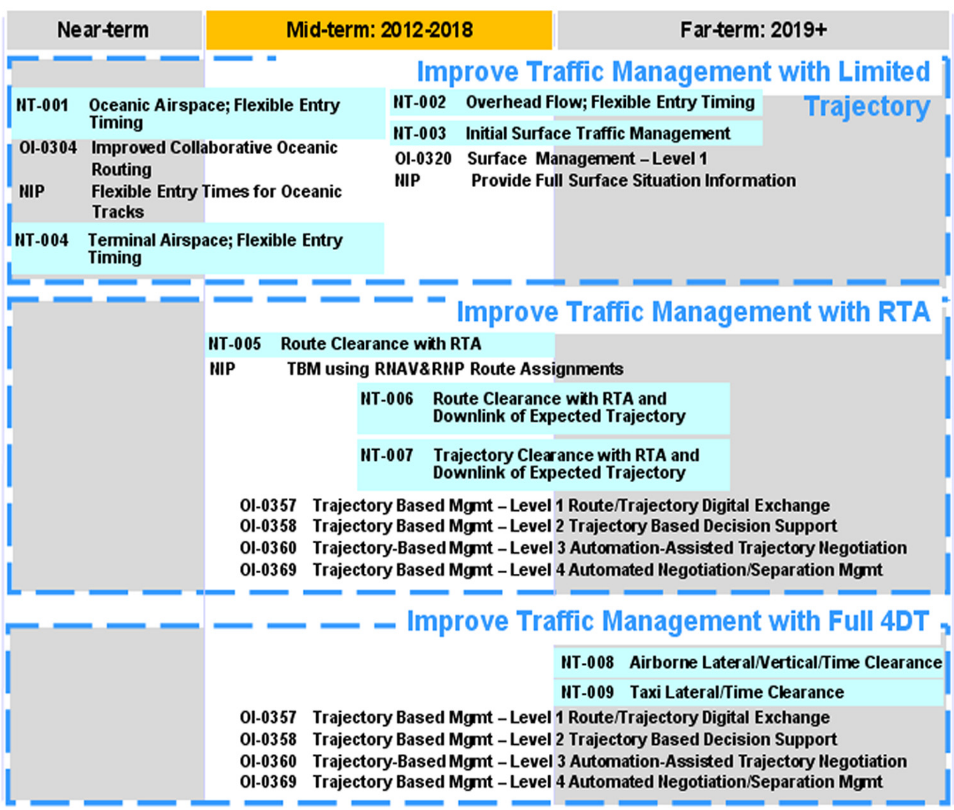
Defining the specifics of TBO, however, has been a gap in the work to encapsulate what is envisioned for NextGen, to include how aircraft can participate using both commercially available and certified data link capabilities. As the capabilities here illustrate, TBO between air and ground can be used at a range of capability levels. All of these levels fit within a TBO framework in which four-dimensional representations of flight trajectories are used to enhance user access to preferred routes and to improve air traffic management. This framework is described in the TBO Framework Appendix 1. The stakeholder community is specifically requested to review this proposal and provide input to help develop consensus on what TBO means and how it is executed in both the near and mid-term.

Few GA aircraft have advanced FMS and fewer have auto-throttles to enable precise 4DT navigation. Therefore the expectation that these aircraft would meet the same stringent requirements of high performance is unrealistic and their 4DT trajectories, therefore, should be adjusted accordingly. It is important to keep in mind that performance based navigation does not always mean extreme precision; it means that the aircraft is able to operate within a performance envelope of its own capabilities.

## TBO Conceptual Framework Highlights

1. Mixed capability, trajectory-based operations form an inclusionary basis for air traffic management everywhere in the National Airspace System (NAS).
2. All aircraft have an associated 4-DT Trajectory.
3. ATM systems should accommodate a heterogeneous aircraft capability in the same operational concept and with the same tools, wherever possible.
4. ATM tools set the required performance.
5. ATM clearances that modify trajectories for managing the traffic may be voice or data, depending on the aircraft and the operation.

*Source: Appendix 1"TBO Framework," NextGen Avionics Roadmap*






| Capability | Key Enablers |
|---|---|
| **NT-001: Oceanic Airspace; Flexible Entry Timing** – Support for user-preferred trajectories is increased through the negotiation and communication of entry times into oceanic airspaces. Operations are supported by voice or data link communications where available. | RNAV, Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer) |
| **NT-002: Overhead Flow; Flexible Entry Timing** – Support for user-preferred trajectories is increased through the negotiation and communication of entry times into en route overhead flows. Operations are supported by voice or data link communications where available. | RNAV, Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer) |
| **NT-003: Initial Surface Traffic Management** – Surface operations and traffic flow management are improved through the availability of aircraft surface position via ADS-B. | ADS-B Out |
| **NT-004: Terminal Airspace; Flexible Entry Timing** Support for user-preferred trajectories is increased through the negotiation and communication of entry times into terminal airspaces. Instrument Flight Rule (IFR) operations are supported by voice or data link communications where available. | RNAV, Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer); Voice Communications |
| **NT-005: IFR Route Clearance with RTA** – Route clearances with a single RTA are communicated to aircraft by voice or data link communications for domestic en route. | Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer), Control Time of Arrival (CTA). |
| **NT-006: Route Clearance with RTA and Downlink of Expected Trajectory** – Ground-based conflict detection is enhanced through the downlink of the aircraft's expected trajectory for domestic en route. | Initial Data Link (FANS 1/A+, ATN Compliant), CTA. |
| **NT-007: Trajectory Clearance with RTA and Downlink of Expected Trajectory** – Air Navigation Service Provider (ANSP) provides aircraft with a lateral and vertical trajectory clearance (e.g., latitudes, longitudes and altitudes), along with a single RTA for domestic en route. | Initial Data Link (baseline), Controlled Time of Arrival (CTA) |
| **NT-008: Airborne Lateral/Vertical/Time Clearance** ANSP provides aircraft, via data link communications, with a lateral and vertical trajectory clearance (e.g., latitudes, longitudes, and altitudes) along with a single RTA. | Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer) |
| **NT-009: Taxi Lateral/Time Clearance** – Full taxi path (including ETAs) clearances are issued to the aircraft via data link communications. | *Data Link (not supported by initial data link enablers)* |

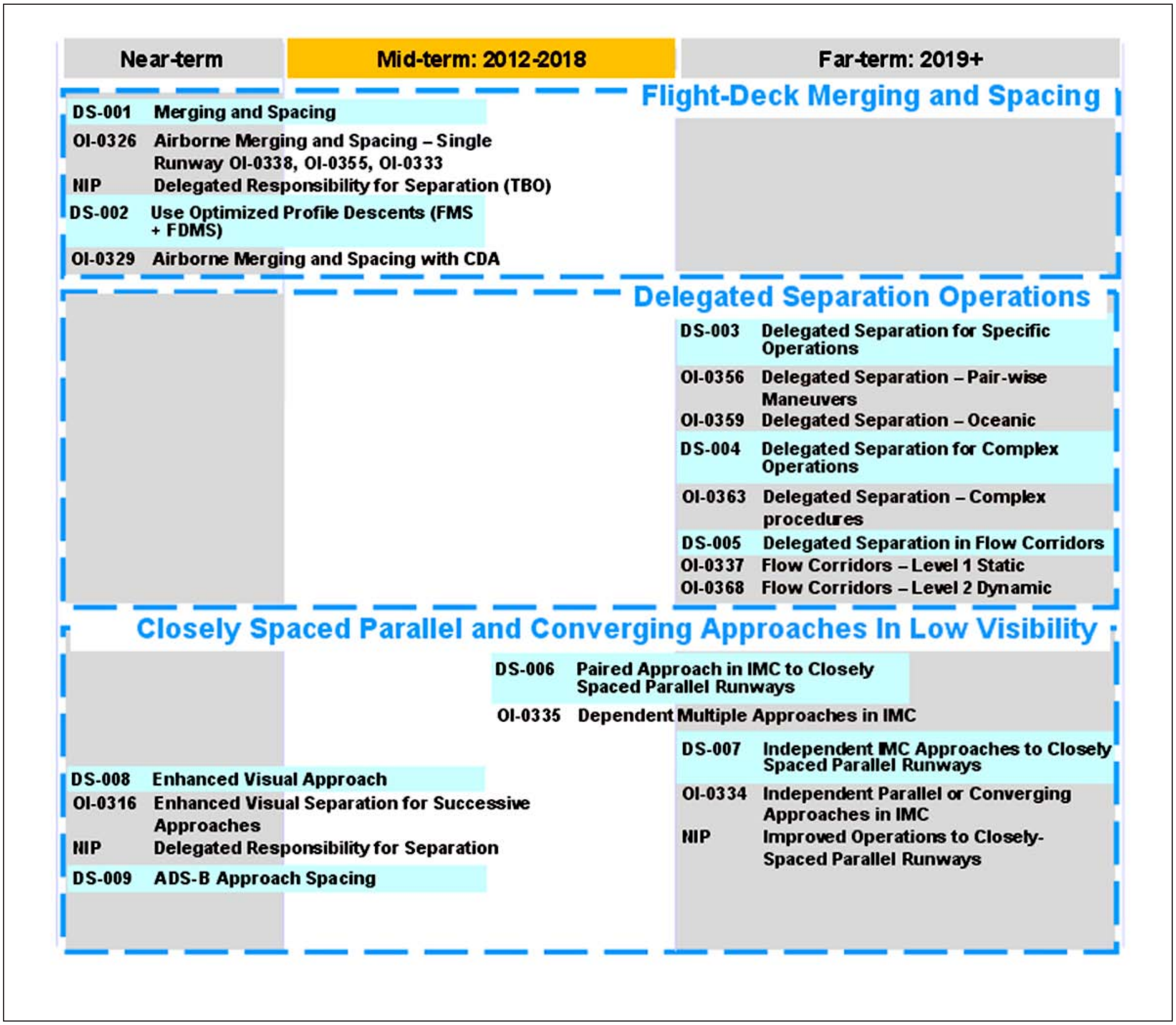
## Delegated Separation

Three capability sub-groups have been identified for Delegated Separation that reflect different levels of avionics functionality and integration.

In the first capability sub-group, ADS-B In and improved avionics capabilities provide the flight deck 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 implement speed changes to achieve and maintain a controller-specified spacing value behind a preceding aircraft, without delegation of separation authority to the flight crew. Additionally, mixed equipage can be supported within a single arrival stream to achieve continuous descent arrivals, with some aircraft having precision airborne merging and spacing capability, and other aircraft being managed by the ANSP provided they are ADS-B Out equipped. Fuel consumption and noise on approach are reduced while maintaining throughput in moderate-to-heavy traffic.

In the second capability sub-group, 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 implement delegated separation between equipped aircraft using established procedures.

In the last capability sub-group, current technologies, such as ADS-B and precision navigation, can be integrated in new ways to support paired approach operations where navigation and cockpit automation reduce the risk exposure. ADS-B enables aircraft to remain above or in front of the wake vortex of an aircraft on the parallel approach, and ADS-B significantly reduces the reaction time to break off the approach in the unlikely scenario of an issue. The achievable runway spacing with these technologies must be determined, so that the business case to equip with these capabilities can be evaluated for current runways and for potential new runway construction.

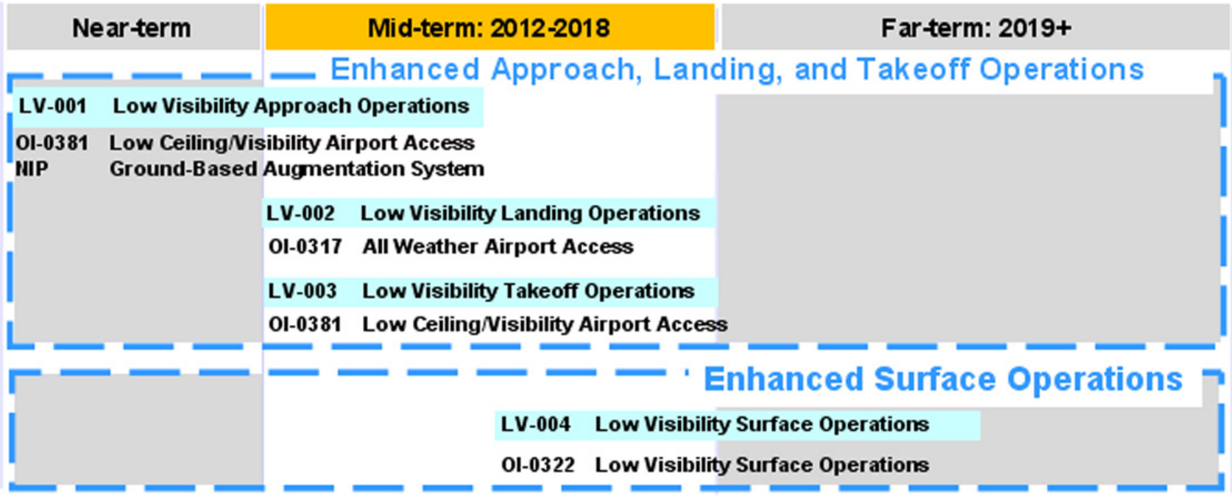


| Capability | Key Enablers |
|---|---|
| **DS-001: Merging and Spacing** – ADS-B and CDTI applications allow improved metering, merging, and spacing operations by allowing an aircraft to achieve and maintain a controller-specified spacing behind another aircraft. | RNAV, ADS-B In, CDTI |
| **DS-002: Use Optimized Profile Descents (FMS + FDMS)** – Flight-deck merging and spacing (FDMS) is applied to aircraft flying optimized profile descents in high traffic environments. | RNAV, ADS-B In, CDTI, Initial Data Link (FANS 1/A+, ATN Compliant) |
| **DS-003: Delegated Separation for Specific Operations** – ADS-B and CDTI applications permit improved efficiency through the delegation of separation responsibilities for specific pair-wise maneuvers (e.g., passing, crossing, turn-behind). | ADS-B In, CDTI |
| **DS-004: Delegated Separation for Complex Operations** – Delegated separation capabilities are further leveraged to allow self-separation in more complex operational scenarios. | ADS-B In, CDTI |
| **DS-005: Delegated Separation in Flow Corridors** Broad availability of ADS-B Out and CDTI applications allow design of specific flow corridors in which parallel streams of aircraft are self-separating. | ADS-B In, CDTI. |
| **DS-006: Paired Approach in Instrument Meteorological Conditions (IMC) to Closely-Spaced Parallel Runways** – Airport capacity in IMC is enhanced through paired approaches (i.e., dependent) to closely-spaced parallel runways that are enabled by ADS-B/CDTI and precision navigation. | ADS-B In, RNP SAAAR, RNP (as required by procedure), CDTI |
| **DS-007: Independent IMC Approaches to Closely-Spaced Parallel Runways** – Runway spacing for independent parallel approach operations using Instrument Landing System (ILS) are reduced based on improved analysis and operational experience. | ADS-B In, RNP SAAAR, CDTI |
| **DS-008: Enhanced Visual Approach** – Single runway capacity in Marginal Meteorological Conditions (MMC) is increased through CDTI-Assisted Visual Separation (CAVS) applications that allow for an aircraft to establish and maintain an assigned spacing separation from the preceding aircraft. | ADS-B (Out for lead aircraft In for trail aircraft), CDTI (trail aircraft) |
| **DS-009: ADS-B Approach Spacing** – Surveillance based on ADS-B Out will increase IMC throughput above the current "one-in, one-out" procedures used in non-radar airspace. This will provide a bridge to using ADS-B In to maintain delegated separation from the previous aircraft, ending either in a visual approach (after acquiring out-the-window references) or an instrument approach. | ADS-B (Out for lead aircraftS In for trail aircraft), CDTI (trail aircraft), *Guidance Display (trail aircraft)* |

### Low-Visibility/Ceiling Approach/ Departure/Taxi

In low-visibility/ceiling conditions, approach, departure, and taxi movement become constrained to ensure safety. The ILS is currently the predominant navigation aid to enable low-visibility/ceiling approaches. Key technologies that may improve airport accessibility include aircraft-based technologies such as head-up display (HUD) auto-approach/autoland capabilities, enhanced flight vision systems (EFVSs), and synthetic vision systems (SVSs), as well as the ground-based augmentation system (GBAS) in combination with GPS.

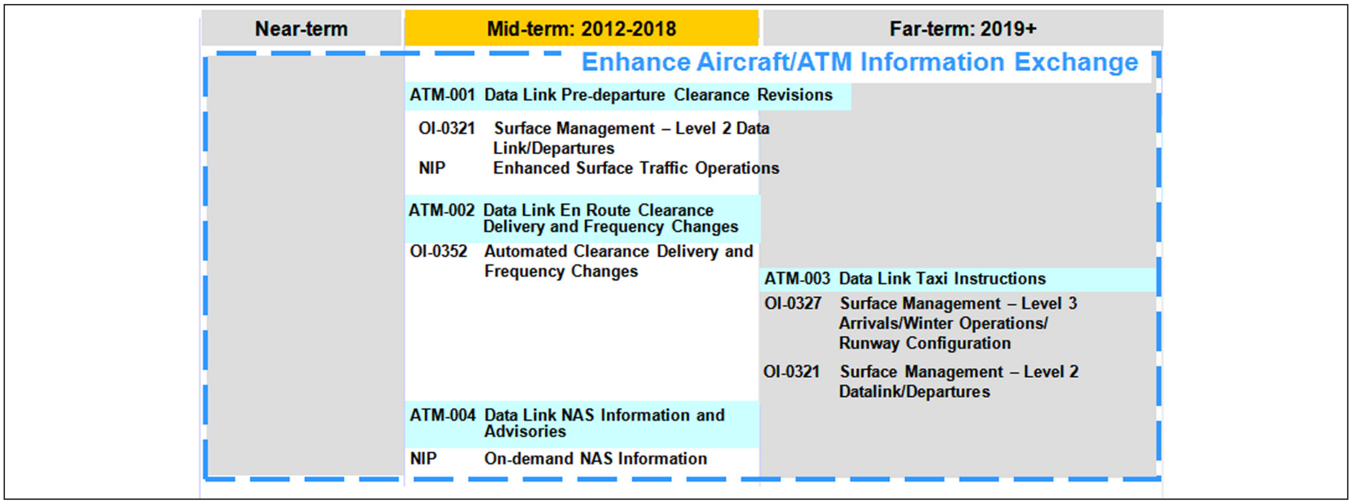
These new aircraft-based flight technologies will allow greater access and throughput at airports that would otherwise be unavailable due to insufficient ground infrastructure. By equipping aircraft with technologies such as HUDs, EFVS, or future technologies, the operator will have greater flexibility and predictability of operations at a variety of airports with less dependence on existing ground infrastructure.

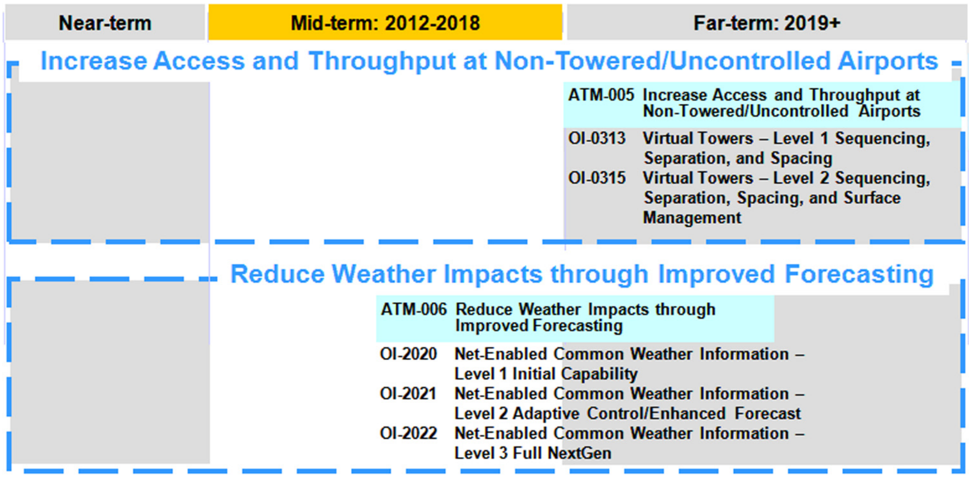


| Capability | Key Enablers |
|---|---|
| **LV-001: Low Visibility/Ceiling Approach Operations** – Airport access in low visibility conditions is improved through reduction in approach minima for aircraft equipped with some combination of augmented GNSS, EFVS, and SVS capabilities. | RNP SAAAR, GLS III, EFVS, SVS |
| **LV-002: Low Visibility/Ceiling Landing Operations** – Airport access is further improved for aircraft in extremely low visibility/ceiling for aircraft equipped with some combination of augmented GNSS, EFVS, and SVS capabilities. | RNP SAAAR, GLS III, EFVS, SVS |
| **LV-003: Low Visibility/Ceiling Takeoff Operations** – Leverages some combination of augmented GNSS, CDTI, EFVS, and SVS capabilities to allow appropriately equipped aircraft to depart in low visibility conditions. Note: GA operating under Part 91 is not affected. | ADS-B In, SVS, EFVS, CDTI |
| **LV-004: Low Visibility Surface Operations** – Low-visibility/ceiling arrival and departure operations are enabled through surface operations (taxi and gate routing) that use some combination of augmented GNSS, CDTI, EFVS, and SVS capabilities to ensure safe operations. | GNSS, ADS-B In, SVS, EFVS, CDTI |

## ATM Efficiencies

In some cases, aircraft avionics can provide improvements to the ATM process that can result in enhancements in services and reduced costs to the FAA. Aircraft key enablers, including data communications and enhanced weather sensors, combine with ground-based decision support tools to provide improvements in Aircraft-ANSP information exchange, access, and throughput at non-towered or uncontrolled airports, and weather forecasting for reduced weather impacts. These capabilities provide direct and indirect benefits to the aircraft and greater overall NAS efficiency.






| Capability | Key Enablers |
|---|---|
| **ATM-001: Data Link Pre-departure Clearance Revisions** – Airport operational efficiency is improved through the issuance of pre-departure clearance revisions through data link communications. | Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer) |
| **ATM-002: Data Link En Route Clearance Delivery and Frequency Changes – ANSP workload is reduced, and operational efficiency** in convective weather is improved through the issuance of en route clearances and frequency changes via data link communications. | Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer) |
| **ATM-003: Data Link Taxi Instructions** – Efficiency of airport operations is further increased by the issuance—via data link communications—of taxi instructions to equipped aircraft. | *Data Link (Not supported by Initial Data Link Enablers)* |
| **ATM-004: Data Link NAS Information and Advisories** – Controller productivity is increased through the issuance of NAS information and advisories (e.g., textual weather, Notice to Airmen (NOTAM), Airport information, departure sequences) via data communications. | FIS-B, Initial Data Link (FANS 1/A+, FANS 2/B, ATN Baseline 1 LINK Post Pioneer) |
| **ATM-005: Increase Access and Throughput at Non-Towered/Uncontrolled Airports** – ATM efficiency is improved through implementation of Staffed Virtual Towers Concept. Leverages data link communications for equipped aircraft, but datalink is not required. | *Data Link (Not supported by Initial Data Link Enablers) and ADS-B Out* |
| **ATM-006: Reduce Weather Impacts through Improved Forecasting** – Aircraft-based weather sensors and data-link communications allow integration of aircraft-sourced weather data into ATM decision-making processes. | *Enhanced Meteorological Data Collection and Reporting System (MDCRS) Sensor, Data Link (Not supported by Initial Data Link Enablers), SWIM/Community of Interest (COI)* |

## First Perspectives: What Does The Roadmap Provide?

Work has been underway for many years to prepare for future aviation needs and challenges. Some of that work has been in development without being specifically associated with NextGen. The challenge from the aircraft perspective has been to determine how these many different and sometimes similar activities relate to one another, and how much of the overall picture we understand. The other challenge is establishing and ensuring good communication between these multiple planning efforts to avoid duplication of work or inadvertent capability gaps.

The following points are noted with respect to emerging aircraft capabilities envisioned through the mid-term.

- Overall, the majority of aircraft capabilities necessary for the mid-term have been previously identified, with many existing in some form of planned development. This roadmap illustrates the relationship between these activities. Future focus should be placed on (1) identifying what capabilities are mature, (2) what additional analysis or study is needed to finalize mid-term requirements, and (3) how to integrate the activities for these capabilities with corresponding ground infrastructure and operator flight planning system changes.

- The work underway through the PBN Roadmap is foundational to NextGen. Nothing new has been presented in the roadmap that identifies the need for additional capabilities. However, refinement in operational requirements (e.g., tighter performance requirements or differing air/ground system allocation) may require aircraft changes.
- A proposed framework for TBO has been provided to illustrate the need for tight integration of aircraft functional capability and performance. The complexity of the solution set will be determined by how enterprise services such as SWIM can work together with certified digital data link. This framework will change as other views are added, however, it does provide a significantly simplified view of how TBO can be conducted with known system functionality.
- A limited number of operational capabilities that were not associated with other known development activities have been identified in the creation of the roadmap. These represent gaps that will be further explored in 2010. These include:
  - TCAS enhancements for higher-density air operations and TBO (SAFE-004)
  - Aircraft-based capability for wake turbulence avoidance and mitigation (SAFE-007 & 008)
  - Improved traffic flow management with limited trajectory (NT-002 & 004)
  - ADS-B Separation (DS-009)

## Deferred Work

As noted previously, the Avionics Roadmap has used material from multiple sources to identify the operational capabilities needed for NextGen avionics and to correlate those with enabling avionics functionality. The objective has been to ensure that NextGen plans reflect the recognition that aircraft capability will evolve over time. Additionally, it is to understand how the various change proposals work together to enable the needed capabilities, as well as address any gaps or shortfalls that are identified.

Work captured in the JPDO ConOps and the IWP has placed very strong emphasis on a variety of avionics functionalities needed to support NextGen operations. In developing this version of the Avionics Roadmap, a deliberate decision was made to limit the scope of work initially to that associated primarily with near-term and mid-term implementation timeframes. Proposed changes involving avionics functionality that would not be implemented until the far-term were largely deferred for the next Avionics Roadmap update. The OIs listed in Appendix 3 reflect those that are considered to have aircraft relevance that will be examined in 2010 and beyond, but were not included in this roadmap because of the far-term timeframe consideration, or because they involved aircraft changes in areas other than avionics.

## Future Work

It is recognized that more work is needed to expand the breadth and depth of information in this Avionics Roadmap. It is also recognized that this information needs to be incorporated into other permanent NextGen planning documents as they are revised. Considering these needs, the JPDO Aircraft Working Group will focus on the following actions in 2010:

1. Mature the content for all six Capability Groups and corresponding enablers presented in the roadmap through the far-term (2019-2025). Considerable focus will be placed on TBO and how this advances the understanding of FMS functions and data communication functions.
2. Incorporate more detailed descriptions of the capabilities and functional performance suitable for airframe and avionics manufacturers and operators to start developing system designs, integration plans, and product development proposals.
3. Outreach—within JPDO as well as with agencies and industry groups, to identify how the JPDO Aircraft Working Group can lead or assist in advancing the work needed for pursuing these aircraft capabilities. It is recognized that significant work is under way in many forums and the Avionics Roadmap and the Aircraft Working Group seeks to further those efforts and not duplicate them. Priority will be given to each of the capabilities noted in Appendix 4 predicted as having greater potential to solve problems in the NAS based on the initial assessment of benefit and risk. This recognizes that multiple views need to be considered in developing the right plans for NextGen.The Avionics Roadmap provides an initial aircraft perspective, however other perspectives need to be integrated to support future planning and decision making.
4. Review and address the needs of the broader user community— GA, Military, and UAS—and the types of aircraft capabilities envisioned for their participation in NextGen. These considerations will be reflected in planned revisions to the Avionics Roadmap. A future workshop is being considered to facilitate broader stakeholder input in this regard.
5. Address the aircraft-related OIs noted in Appendix 3 with regard to how they should be incorporated into this roadmap or addressed through other actions.
6. Work with the JPDO's Interagency Portfolio and System Analysis (IPSA) division to refine benefits, risk, and cost assessments associated with the content captured in this roadmap. Use this information to guide future work and ultimately to confirm the right set of aircraft capabilities and avionics enablers have been identified.
7. Identify how information from the Avionics Roadmap should be incorporated into other NextGen planning documents when they are revised.

To better understand the capabilities illustrated in this roadmap, and to efficiently plan future work on how to mature these capabilities, an initial assessment was performed examining the benefits and risks associated with each capability. Details are provided in Appendix 4. It should be noted that the assessment was based on existing data and did not consider cost or broader implications (e.g., ground system infrastructure investments, and potential conflicts with capabilities that may emerge in the far term or in consideration of other industry and agency commitments). This assessment, while limited in scope, reflects a valuable first step in assisting the Aircraft Working Group identify where greater priority should be given in terms of interfacing with other groups and activities, both within and outside of the JPDO. It is also recognized that other relevant capablitity data sources likely exist beyond what was readily available to support this first assessment.

## Closing

This Avionics Roadmap focused on air carrier, high end business aircraft operations and avionics capabilities through the mid-term (2018). Version 2.0, which will be produced in the future, will address far-term capabilities and requirements and the needs of the other user communities. Version 2.0 will provide airframe and avionics manufacturers and operators the details needed to begin the necessary planning, development, and implementation of the equipment needed to enable future NextGen capabilities.

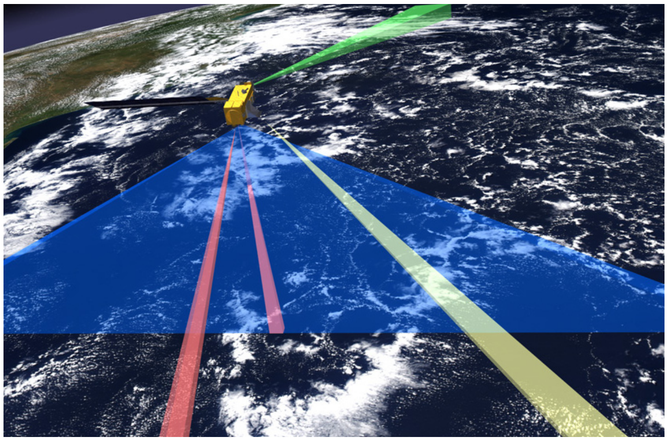
### Air Traffic Management Efficiencies/Airline Operations Centers (AOC)/Systems Operations Center (SOC)

In some cases, aircraft avionics can provide improvements to the ATM process which results in reduced costs of operations to the FAA or enhancements in services. Aircraft key enablers, including data communications and enhanced weather sensors, combined with improved ground-based decision support tools, provide improvements in Aircraft – ANSP– SOC information exchange. This includes access and throughput at non-towered or uncontrolled airports and weather forecasting for reduced weather impacts. These capabilities provide direct and indirect benefits to the aircraft associated with improved overall NAS efficiency. This solution set covers strategic and tactical flow management, including regulatory critical interactions with operator's SOC to mitigate situations when the desired use of capacity cannot be accommodated. The Collaborative Air Traffic Management (CATM) solution set includes flow programs and dialogue on procedures that will shift demand to alternate resources (e.g. routings, altitudes, and times). CATM also includes the foundational information elements for managing NAS flights with the stakeholder's AOC/SOC. These elements include development and management of aeronautical information, airspace reservations, and flight information from pre-flight to post-flight analysis.

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 NAS user's AOCs/SOCs. 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 AOC/SOC to meet stakeholder demand while ensuring highest level of safety, throughput and regulatory requirements.

With Flexible Airspace Management, ANSP automation supports reallocation of trajectory information (4DT), surveillance, communications, and display information to different positions or alternate facilities. Additionally, working with the AOC/SOC allows maximum utilization while maintaining the highest level of safety. These 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 curtailed due to limitations of automation, surveillance, and communication capabilities, such as primary and secondary radar coverage, availability of radio frequencies (Data Comm), and ground-communication lines. New automated tools in the ANSP, Aircraft, and AOC/SOC will define and support the assessment of alternate configurations, as well as remapping of information (e.g., flight and radar) to the appropriate positions.



These improvements are not just pertinent to communications, but advancements to flight planning systems make best use of all available routes fully utilizing SWIM and implantation of System Enhancements for Vehicle Electronic Navigation (SEVEN) towards a true Collaborative ATM system. This active collaboration facilitates NAS users to maximize negotiated routes while mitigating present and future delays. Advancements, while still maintaining regulator standards with crews, AOC/SOC, ANSP, to achieve specific navigational trajectories such as TBO's via various data link communication grow the NextGen ATM vision and efficiency.

| Near-term | Mid-term: 2012-2018 | Far-term: 2019+ |
|---|---|---|

## Enhance Aircraft/ATM Information Exchange

**Mid-term: 2012-2018**

**ATM-001 Data Link Pre-departure Clearance Revisions**
- OI-0321 Surface Management – Level 2 Data Link/Departures
- NIP Enhanced Surface Traffic Operations

**ATM-002 Data Link En Route Clearance Delivery and Frequency Changes**
- OI-0352 Automated Clearance Delivery and Frequency Changes

**ATM-004 Data Link NAS Information and Advisories**
- NIP On-demand NAS Information

**Far-term: 2019+**

**ATM-003 Data Link Taxi Instructions**
- OI-0327 Surface Management – Level 3 Arrivals/Winter Operations/ Runway Configuration
- OI-0321 Surface Management – Level 2 Datalink/Departures

## Increase Access and Throughput at Non-Towered/Uncontrolled Airports

**Far-term: 2019+**

**ATM-005 Increase Access and Throughput at Non-Towered/Uncontrolled Airports**
- OI-0313 Virtual Towers – Level 1 Sequencing, Separation, and Spacing
- OI-0315 Virtual Towers – Level 2 Sequencing, Separation, Spacing, and Surface Management

## Reduce Weather Impacts through Improved Forecasting

**Mid-term: 2012-2018 to Far-term: 2019+**

**ATM-006 Reduce Weather Impacts through Improved Forecasting**
- OI-2020 Net-Enabled Common Weather Information – Level 1 Initial Capability
- OI-2021 Net-Enabled Common Weather Information – Level 2 Adaptive Control/Enhanced Forecast
- OI-2022 Net-Enabled Common Weather Information – Level 3 Full NextGen



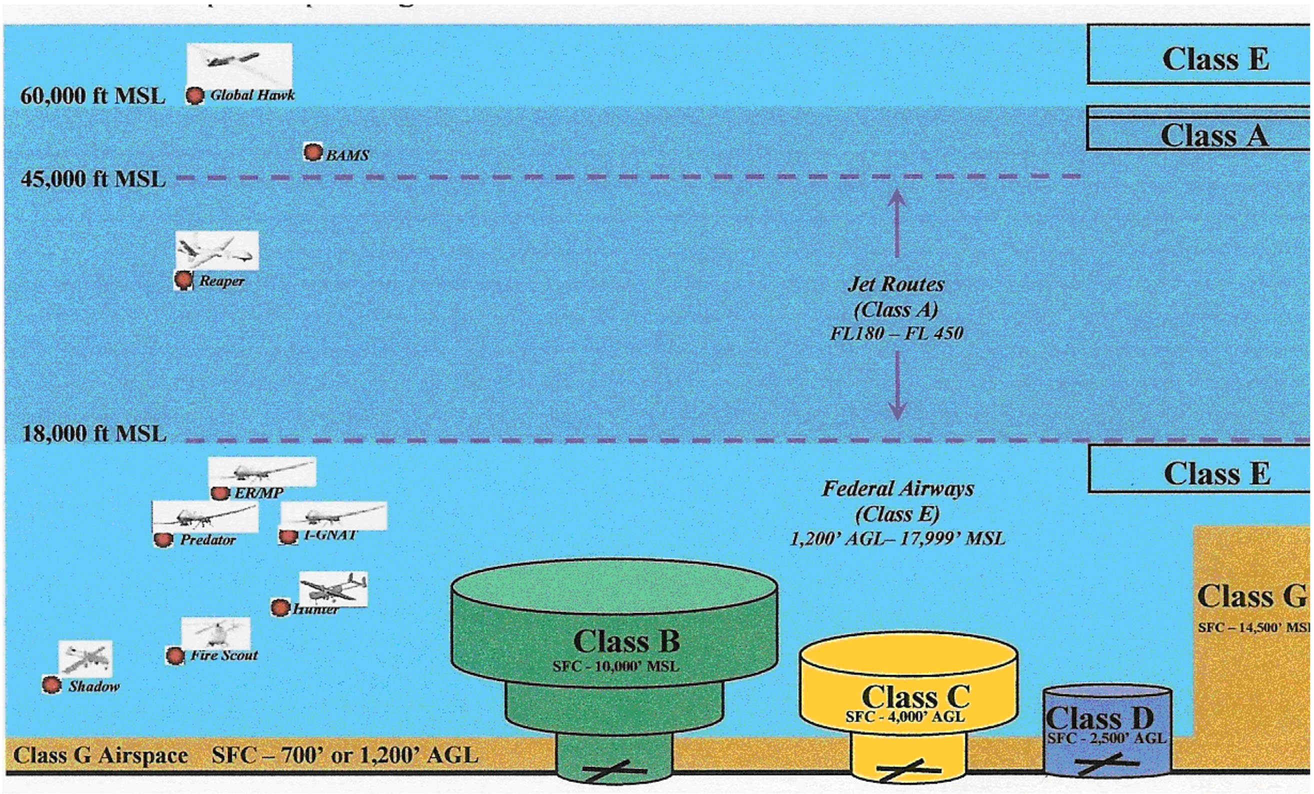
## Unmanned Aircraft Systems (UAS)

This section of the Avionics Roadmap presents Aircraft Working Group (AWG) discussions on UAS file-and-fly access in the the midterm NAS plan. The section addresses the following issues: NAS Enterprise Architecture (NASEA) action, Congressional action, and UAS roadmaps/flight rules.


In the 2008 NASEA, contained a "green diamond" statement indicating that UAS access would be authorized in the NAS in 2018 and that certain, unspecified Research and Development (R&D) was required. This section presents a follow-on discussin to the "green diamond" statement.

One of the core issues in addressing UAS access to the NAS is categorizing the UAS vehicles into mission, performance, and capability categories. From an avionics perspective, these categories will play an important role in understanding where the vehicles will operate, and thus the avionics requirements needed. Assumptions will need to be made with regards to Visual Flight Rules (VFR) versus Instrument Flight Rules (IFR) operations, mission roles, operating areas and, perhaps most important, how UAS will transit to and from those operating areas.

The graphic below illustrates the envisioned operating airspace envelopes for a sampling of UAS types:



UAS that operate exclusively within restricted airspace or in Class G airspace will likely be exempt from meeting FAA regulations regarding aircraft certification requirements. However, as UAS operations expand outside these areas either for mission purposes or transiting to and from restricted airspace, FAA regulatory guidance or the military equivalent will apply to their operations. Avionics requirements will depend on the degree of compliance necessary, where they operate, and the traffic density of the airspace.

The term UAS covers a broad range of vehicles. The UAS Program Office (UAPO) has created 3 UAS groupings based on maximum takeoff gross weight, operating altitude, and speed. These groupings have been broken down further based on required FAA regulation and airspace usage as illustrated in the figure below.

| | | Certified Aircraft / UAS (Cat III ) | Nonstandard Aircraft / UAS (Cat II) | RC Model Aircraft / UAS (Cat I) |
|---|---|---|---|---|
| FAA Regulation | | 14 CFR 91 | 14 CFR 91, 101, and 103 | None (AC 91-57) |
| Airspace Usage | | All | Class E, G, & non-joint-use Class D | Class G (<1200 ft AGL) |
| Airspeed Limit, KIAS | | None | NTE 250 (proposed) | 100 (proposed) |
| Example Types | Manned | Airliners | Light-Sport | None |
| | Unmanned | Predator, Global Hawk | Shadow | Dragon Eye, Raven |

Vehicles that will operate under FAR Part 91 will need to consider required avionics capabilities, vehicle certification, and operator qualification. Another key element will be establishing the integrity of data link range limits and abnormal operations (e.g., loss of data communication).

The current UAS Roadmap in the NextGen Enterprise Architecture provides a decision point in the 4th quarter of 2011 when NextGen planners will move forward with developing requirements for the UAS performance envelope.

## Surface Operations

This section describes the surface operations and projected aircraft avionics requirements that are expected to exist in the NextGen midterm period from 2010 to 2018. It is based on the hypothesis that the responsibilities between the flight crew and Air Traffic Control (ATC) remains roughly the same as today for operations on the airport surface, i.e. Ground ATC defines and decides the taxi route that the aircraft should follow and provides, the aircraft crew with clearances along this path, whereas the aircraft crew has to execute the taxiing according to the received clearances. It also assumes that there will be some level of data link communication used to reduce voice communication. Currently, the aircraft has few specific avionics means to facilitate surface operations. New avionics capabilities becoming more widely available in the later part of the midterm (2015-2018) will increase safety of operations for approach/departure and taxi.

## Safety Enhancements, Hazard Avoidance, and Mitigation (SAFE 0005)

Surface moving maps with overlaid “ownship” (SAFE 0005) position information will improve flight crew situational awareness in ramp areas, taxiways, and runways helping to reduce runway incursions. Such moving maps may be presented on electronic flight bags (EFBs) or preferably on the Navigation Display. Graphical qualities, modes, and ranges, as well as Human Machine Interface (e.g., interactive) will depend on the specific installation. This capability will require GNSS position information in conjunction with high integrity airport map databases. Initial implementation will begin in 2010. Some of the desired capabilities identified by SAFE 005 are listed below.

1. **OwnShip Surface Relative Position**
   This capability will aid flight crews by providing better situational awareness of their own position relative to the locations of runways along their route of taxi, resulting in greatly reduced occurrences of runway incursions.

2. **Indication of Runway Identifier Toward Which the Aircraft is Approaching**
   This capability aids in positive runway identification to eliminate confusion as to the aircraft location with respect to active runways. This function may also be used to provide positive verification of the assigned departure or landing runway.

3. **Approaching Runway Alerting Without Line-up Clearance**
   This capability alerts the flight crew when approaching the takeoff position and the aircraft has not yet received its line up clearance, thus avoiding a possible runway incursion. This would occur when an aircraft is occupying the runway or is on final approach in close proximity to the threshold.

4. **Final Approach Runway Occupancy Alerting (FAROA)**
   In this capability, an alert is provided to a landing aircraft on final approach when the runway is occupied by another aircraft or vehicle. While not a surface movement capability per se, it does provide situational awareness to an aircraft on final approach by providing it with information about aircraft on the runway or approaching the runway. This significantly reduces the potential for error, especially in low visibility conditions for issuance of a landing clearance with another aircraft on or moving onto the landing runway.

5. **Insufficient Runway Length and Alerting**
   This capability improves crew awareness of runway distance available at the start of the takeoff roll and provides remaining runway distance during the landing roll. It will provide an alert when there is insufficient runway distance required to complete the takeoff or landing maneuver. During the landing maneuver, this aids the decision process for the crew to determine if additional deceleration is necessary to stop within the remaining runway distance.

6. **Runway Exit Indication**
   This capability provides situational awareness based on the known deceleration rate of the aircraft and its ability to exit the runway at a specific taxiway. This will allow the flight crew to optimize the deceleration rate of the aircraft, minimize time on the runway, and determine if additional thrust is required to taxi up to a runway turnoff position.

7. **Other Ship Situational Awareness**
   This capability uses a moving map display to show the locations of other aircraft or vehicles in proximity of own ship.

These capabilities are displayed on the surface moving maps and the alerts will be provided by characteristic aural messages and tones. New algorithms will be required in most existing flight management computers (FMC) to compute takeoff and landing performance. A traffic computer receiving inputs from ADS-B In and/or Traffic Information Service Broadcast (TIS-B)will be necessary to support the aircraft-to-aircraft functions and a database incorporating essential surface data (runways, taxiways, ramps, etc.) will be needed to support the surface movement applications. As these capabilities evolve, the level of integrity and accuracy of the information will have to increase to support the more critical operations.

Early implementation of these capabilities will begin in the 2010-2015 timeframe and will include basic surface movement indication and alerting functions. More advanced applications are expected to become available in the late mid-term or early far-term periods and will first appear in new aircraft designs. Additionally, these capabilities will be offered as retrofit packages to existing aircraft.

## Improved efficiency of taxiing operations

During periods of high traffic density and poor visibility, the following aircraft capabilities will allow for less dependence on costly ground infrastructure.

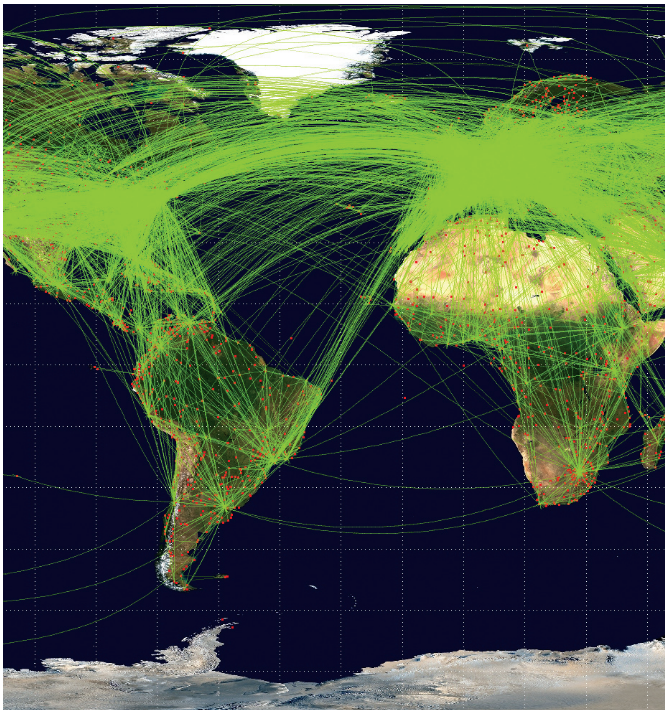
1. **Manual Input of Taxi Route Clearances**
   Taxi clearances received via Data Link (e.g.VDL-2) may be up-linked to the aircraft into a communications management unit (CMU) and then manually transferred to the FMC or EFB to provide a visual depiction of the route on the moving map display. As an interim solution, it may be acceptable for the flight crew to manually insert aural or digital taxi clearances into the FMC or EFB. Toward the end of the mid-term and early far term, this capability will be automatically downloaded and available for pilot selection to the moving map display. In the far-term, additional capability may come in the form of taxi clearances that include a time element from first movement off the gate/parking spot to the end of the runway. Initial implementation of these capabilities is expected to occur in the 2013-2018 timeframe.

2. **Braking Assistance**
   A brake monitoring system will provide automatic braking and indications to the flight crew as to an assigned runway turnoff point. It may be used either in an automatic braking mode or as an indication of deceleration progress to the assigned turnoff point. This system will help reduce brake wear and runway occupancy time.

   Initial implementation is expected to occur in the 2010-2013 timeframe with the automatic braking function occurring in the mid-to far-term period.

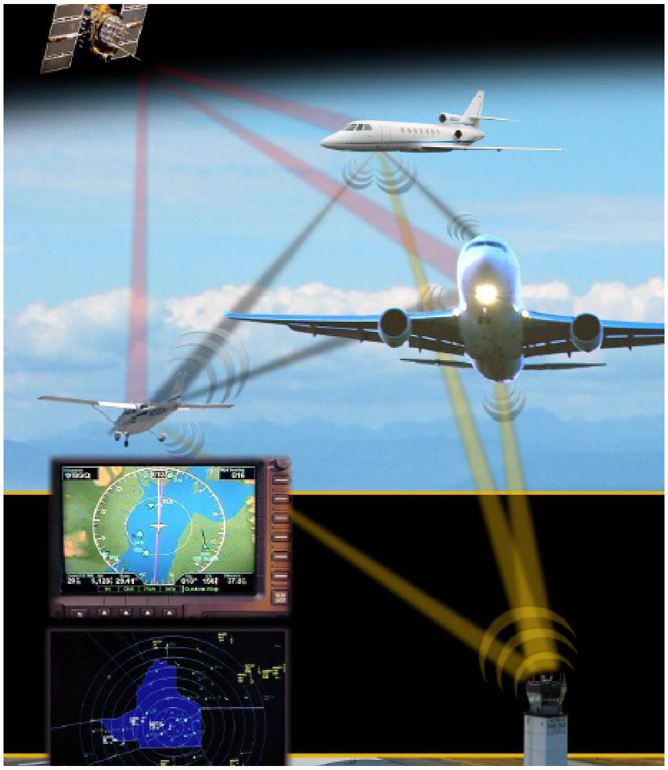
The following key enablers are required for implementing those functionalities:

1. **Airport Map Database (EN0225 and EN0226)**
   Existing Airport Map Databases are suited for short-term surface functionalities, which are basically advisory and situational awareness capabilities, consisting mainly of a display of the airport features or layout. For the more advanced applications envisioned, the accuracy and integrity of the databases will need to be increased.



Additionally, Airport Map Databases, which are currently a graphical depiction of the airport elements, will be complemented by connectivity data linking the different airport elements, as required by the upcoming new surface functionalities.

In the far-term, the airport map data elements will be uplinked to the aircraft through a defined network in order to ensure consistency of the airport map data elements displayed and/or used by the aircraft crew and ATC.



2. **Accurate Aircraft Position**
   Most of the mid-to-far-term surface functionalities will rely on augmented GNSS position information such as Wide Area Augmentation System (WAAS). However, accuracy and integrity improvements may be required for more advanced surface functionalities in the far term.

3. **ADS-B, TIS-B and Multilateration**
   These are key enablers for all traffic related surface functionalities. ADS-B In aircraft position on the airport surface will need to comply with the specific accuracy and integrity requirements for such surface functionalities.
4. **Controller Pilot Data Link Communications (CPDLC) Interface**
   This enabler not only involves the airborne side but also requires the ground side to provide such capability.

As an abbreviated summary, on-board systems are composed of all or a part of the following:

- Airport Moving Map Systems
- Cockpit Displays & Controls
- Traffic computers with ADS-B and/or TIS-B capability
- Enhanced Vision (HUDs, Surface Guidance Systems, Enhanced Vision Systems)
- Communication Management Units (CMU)
- Potential Database Servers
- Braking Systems
- Flight Controls and Auto-Throttle

## Appendix 1: TBO Framework

A sizable gap in the NextGen's ConOps has been the lack of specificity for TBO, particularly in the area of definition for a 4D trajectory (4DT) and how TBO depends upon and utilizes 4DT. This appendix proposes a definition of the elements of a 4DT, and will attempt to provide insight into how TBO would utilize 4DT to manage the airspace. As the various sections of this roadmap illustrate, TBO between air and ground can be used across a range of capability levels. All of these levels can fit within a TBO framework where four-dimensional representations of flight trajectories are used for implementing air traffic management.

### Highlights of This Conceptual TBO Framework Are:

1. Mixed capability, trajectory-based operations form an inclusionary basis for ATM everywhere in the NAS. It is inclusionary because performance levels and functional capability requirements for specific times and routes are set by ATM based on demand, and the system is able to handle aircraft of mixed capability levels everywhere. As performance requirements tighten however, lower performers may have reduced access, but only during those times.
2. All aircraft have an associated 4DT, whether completely or partially generated on the aircraft and data-linked with the ground systems using or completing the 4DT, or generated from a flight plan filed by voice and turned into a 4DT by ground systems. This allows for mixed capability operations where aircraft of differing capability can be managed in the same way throughout the NAS by service providers who have a single mode of operation (TBO) for all aircraft. It is key that ATM systems be the repository for all trajectories and that they will all be 4DT with varying levels of performance required based upon capacity-driven need and aircraft capability.
3. The transition to 4DT starts with improvements to ATM systems that support a 4DT concept of operations and take advantage of the data communications capability in some existing aircraft. ATM systems should accommodate a heterogeneous aircraft capability in the same operational concept and with the same tools, wherever possible, to enable early benefits and to allow the airborne system evolution to proceed independently, driven primarily by the operator's need for access and flexibility.
4. While a 4DT is negotiated and set prior to flight, ATM tools set the required performance (in all four dimensions), set windows (as needed) within which trajectories may be placed (all four dimensions), and set constraints (as needed) where trajectories may not be placed. Windows can collapse to points, i.e., an altitude window can become a hard altitude constraint if there is no flexibility left in accommodating traffic demand. These are the primary parameters that need to be exchanged between aircraft and ANSP systems. Trajectories are moved as necessary through rerouting (modifying the trajectory points), shifting of windows, or modification of constraints.
5. ATM clearances that modify trajectories for managing the traffic may be voice or data, depending on the aircraft and the operation, with the performance level associated with each trajectory known by the ground systems and handled accordingly. Data allows more complex clearance and revisions, and voice provides an exception mode and provides simpler services to unequipped aircraft. Clearances may add or modify windows, may set required performance levels or constraints for a 4DT, or provide revisions to the routing of the intended trajectory.

## Evolving Air Traffic Operations

TBO provides a framework within which integrated planning, decision making, negotiations, and execution of operations may be performed based upon variable demand and performance capabilities forming a total system concept. In this total system, the use of ground-based tools, aircraft decision support tools, planning and processes, and human interfaces are all integrated to optimize the operational solution. TBO with performance attributes has been embraced as a central theme of both the U.S. NextGen and European SESAR Concepts of Operations. The material included below is presented as a conceptual framework for unifying the representation of different alternative elements within the NextGen concepts, while also allowing for the transition stages along the way. The following two paragraphs will briefly describe the concept and phases of Trajectory Based Operations.

## Concept of Operations

The fundamental requirement of NextGen is to safely accommodate significantly increased traffic, and to do this in airspace that is already congested, such as between heavily traveled city pairs (such as Washington and Chicago) and near the busiest airports. It is also advantageous to the flow of traffic to attempt to manage all traffic in similar ways, homogeneously handling all aircraft by trajectory with varying levels of capability and setting the required capability dynamically in response to changing situations and density needs. This requirement leads to a transformation of the national airspace to TBO, in which precise management of an aircraft's current and future position enables increases in throughput and improvements in efficiency when necessary by varying the level of performance required to meet the need. All airspace operations are based upon trajectory and are inclusive of all capability levels of aircraft with flexibility inherent in the trajectory clearance that sets the performance required at that time, and allows for the aircraft to optimize performance within some bounds or allows the aircraft some maneuverability to resolve delegated separation to other aircraft.

The following sections will expand upon this concept of operations, and will propose in more detail the elements of a 4DT and their uses in the phases of operation.

## The Phases of Trajectory Operation

Having discussed the high level concept of trajectory-based operations, this roadmap will describe a possible phased method of operation under TBO, with a more detailed possible definition for 4DT to follow.

There could be four phases to TBO: pre-negotiation, negotiation, agreement, and execution.

Pre-negotiation: As described in the operational concept, all trajectories in the airspace and on the aircraft surface must satisfy a set of constraints. Constraints are not unique to a single trajectory; they apply to the system itself. A thunderstorm can impose a constraint where access to certain airspace is not available, and forecast storms can impose constraints on traffic densities to build in sufficient maneuverability. Other constraints may be defined, based on limited airport capacity. From the aircraft operator's perspective, the pre-negotiation phase involves the definition of the trajectory objectives: where do I want to fly, when do I want to fly, and how would I like to get there? Aircraft constraints are also defined during this phase, such as limits on the types of approach operations that can be flown.

Negotiation Phase: During the negotiation phase, operators use all available information to determine their trajectory objectives and negotiate that with the ANSP to determine feasibility. The operator may accomplish this through flight planning prior to departure, aircraft systems while in flight, or through a flight operations center. Similarly, the ANSPs use all available information to determine the trajectories that make the most efficient use of available airspace and negotiate that with the operator.

The operator and the ANSP need to consider current and forecasted weather, any special use or otherwise restricted airspace, and any other aspects that may restrict the achievable trajectory (e.g., availability of navigation aids suitable to support the operation). The successful completion of the negotiation phase is the agreement phase. Note that the negotiation phase can also be entered due to unanticipated changes during the execution phase. For negotiation that occurs during in-flight operation, there is a requirement for timely completion of the negotiation phase. In the limit, during operations where immediate action is required by the controller to assure safe separation, the negotiation phase may be skipped and proceed immediately to the agreement phase.

*Agreement Phase:* The agreement phase is very brief and consists of the request for and acceptance of a trajec-

tory clearance. Trajectory clearances will set the window and performance requirements for all four dimensions, although they may not be addressed simultaneously (as is the case with future operations and change in altitude along a route). The intended trajectory is not included in the agreement phase, other than the degree to which it is constrained by the trajectory windows. Any validation of the trajectory needed to commit to the trajectory, for the operator or the ANSP, is accomplished as part of this phase. For example, when the ANSP grants a clearance request, the ground automation system must provide some assurance that the aircraft can operate along the trajectory without interference, provided there are no unanticipated changes in the environment (e.g., weather, traffic). An unsuccessful agreement phase returns the trajectory to the negotiation phase, while a successful agreement phase leads to the execution phase. Note that an actual clearance may only affect a portion of the trajectory at a time, such as a change in assigned altitude.

*Execution Phase:* During the execution phase, the aircraft maintains a trajectory within the window defined in the clearance and with performance that satisfies the performance requirement of the agreement. In the far-term with full four-dimensional trajectories, the trajectories are designed during the negotiation phase to satisfy the demand on the system from scheduled and unscheduled traffic and events, and to minimize interaction and changes during the execution phase. The aircraft will monitor compliance with the agreement (as will the separation function of ANS) and if, for any reason, the aircraft can no longer comply with the clearance, it must be alerted and the trajectory renegotiated. Ideally, this would occur prior to actually changing the trajectory. However, where immediate action is required by the aircraft to ensure safe separation is maintained (e.g., TCAS resolution advisory), the trajectory change is made prior to renegotiation. It may also be necessary for the ANSP to renegotiate the clearance. This may arise due to unanticipated changes in weather, failures of aircraft equipment or supporting ANSP infrastructure, or as a result of changes in the trajectories of other aircraft.

## Relationship to ConOps ATM TBO Functions

The phases of trajectory operation can be related to the ATM functions that have been identified for TBO, and are being developed within the ANS working group of the JPDO. As the definitions of those functions are refined, the relationship between the aircraft perspective described here and the ATM perspective will be elaborated.

## TBO and Delegated Separation

Safe separation between actual trajectories must be maintained during the execution phase of all trajectories. The responsibility for monitoring that separation is maintained during any phase and can lie with the controller (e.g., IMC operations) or the flight crew (e.g., VFR operations). Where separation is the responsibility of the controller, separation is reflected in the trajectory clearance of the aircraft involved. Achieving optimal spacing may involve applying tight window constraints to the trajectories and renegotiation of the trajectory as improved information becomes available (weather or the actual trajectories of aircraft). In contrast, where separation responsibility is delegated to the flight crew, the flight crew must have some flexibility in their trajectory clearance that enables them to maintain the required separation without renegotiation with the ANSP. As such, larger window constraints are required. This affords greater flexibility to the aircraft at a tactical level, and relaxes certain aspects of the aircraft performance requirements such as the flight technical error, while demanding greater performance from other aspects of the system such as ADS-B. The tradeoffs between these separation concepts will need to be further evaluated to determine the best allocation of requirements between the aircraft and ground systems.

## TBO and Information Exchange

In order to improve efficiency, it is critical to provide access to high-quality information during all phases of planning and execution, including the negotiation phase. This includes access to system wide constraints such as forecast and tactical weather, airspace, aircraft performance, traffic, and environmental. For this phase, there is a need for net-centric communications whereby all available data that affects the planning is accessible to all constituents. This data is planned to be hosted so that it can be requested from any authorized user within the network. For aircraft operators, they may choose to rely primarily on their FOC to access this data and negotiate the trajectory, or may provide access from the flight deck and empower the flight crew to negotiate this trajectory. The allocation of this function between the aircraft, ANSP, and the AOC is another key consideration in defining the future aircraft. In order to optimize the execution of the trajectory, information needs to be presented in a consistent way that is both timely and accurate. Each of the constraints described will be processed by decision support tools that will reside either within the ground automation or on-board systems. To allow this information to be consumed seamlessly, each of the constraints will need to be represented in a consistent format. This will allow airspace, traffic, terrain, weather, obstacles, and other system limitations to be communicated effectively throughout the system. To manage costs for implementation, the information elements need to have performance parameters assigned based on how that information will be used and the effect of the decision made from that information. Information performance will be used to determine which of the available connectivity methods will be appropriate for delivery and confirmation. Different technologies may be chosen for ground-ground and air-ground exchanges of information depending on whether the information is being used for planning, negotiations, or trajectory execution and monitoring. In this framework, the certified data link system would be required for support of the TBO agreement phase, while other technologies, such as SWIM, could support both the pre-negotiation and negotiation phases. This is consistent with the overall performance-based operational nature of the system. It allows the communications assets to be flexible and scalable based on the necessary performance for the intended operation.

### The 4DT Trajectory Object Defined

The trajectory describes the path of the aircraft through four dimensions: lateral (1) latitude, (2) longitude, vertical (3) altitude, and (4) time. While the actual trajectory is uniquely known after it is flown, there is always some uncertainty with respect to the aircraft execution of the intended trajectory. The trajectory object should consist of a set of parameters that completely describe the intended trajectory. The following elements could be considered to be components of that object:

_Trajectory objectives:_ The objectives (like the SESAR concept of "business trajectory") should contain information describing the aircraft operator's objectives for a particular flight. A conventional IFR flight plan is an example: it describes where the operator wants to go, when they want to go, and their preferred route. (A route is not a continuous set of trajectory points, rather it is a discrete representation of a full trajectory).

_Intended trajectory:_ Intended trajectory is the continuous trajectory that the operator intends to take, and would take if there were no errors or uncertainty in executing the flight. For example, a repeatable and predictable definition of the lateral aspect of a trajectory was developed as part of Required Navigation Performance Area Navigation (RNP-RNAV). It was defined in RTCA/DO-236 as the desired trajectory but referred to in a general context as the intended trajectory to clearly distinguish it from the trajectory objectives.

_Actual trajectory:_ Actual trajectory is the aircraft trajectory that is flown. The actual trajectory can differ from the intended trajectory due to errors in the control loop: e.g., in the estimated position of the aircraft, in the definition of the intended trajectory, and in residual control error (i.e., flight technical error in the lateral and vertical dimensions). The actual trajectory only exists behind the aircraft, up to the current aircraft position and velocity.

_Window:_ A window is a conceptual extension of the common example from current operations, i.e., the vertical trajectory during an altitude transition. In this case, the controller can assign a new en route altitude for the aircraft to descend or climb to, but the specific path to be taken by the aircraft, i.e. the rate of descent/climb, is frequently undefined. By extension, there could be an allowable region (in any dimension), within which the ANSP will allow the aircraft to relocate or revise its intended trajectory subject to the limits of its required performance (the aircraft is assumed to be complying with the requirement). While it would be initially specified relative to the intended trajectory, once defined it would become fixed in space/time. In many cases, there may be no flexibility in the intended trajectory, and the window would have to collapse to be identical to the intended trajectory itself. This window has also been referred to as a flexibility volume, emphasizing that it has multiple dimensions and describes the trajectory flexibility that is granted to an aircraft.

*Performance:* There would be performance requirements that describe how closely the aircraft's actual trajectory must adhere to the intended trajectory and extensions from the lateral performance requirements that are captured in the RNP designation, which indicates accuracy and integrity requirements. The performance requirements must address the total system error between the actual trajectory and the intended trajectory. These performance requirements would be levied by the ANSP as part of the trajectory, whether static or dynamic. However, there is another aspect of performance--achieved performance-- estimated by the aircraft and used to assure compliance with the ANSP required performance. (Example: Air Navigation Plan (ANP) vs RNP alerting for RNP operations). As in the RNP concept, the tool available to ANSP could be the required performance, with the aircraft having the responsibility to comply or advise unable. This would free ANSP from estimating aircraft performance aside from having knowledge of the best levels that may be available for use in a dynamic situation.

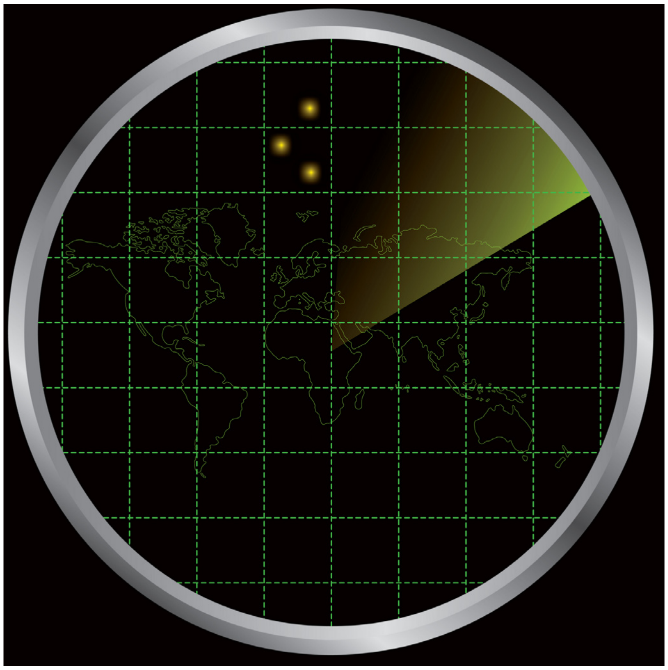
In order to define a complete trajectory object, it would be defined in all four dimensions. It would consist of lists of parameters (such as a series of latitudes and longitudes to identify a fix in the plan, or altitudes to identify constraints) and common algorithms (e.g., connecting fixes by geodesic paths) to construct the complete, continuous trajectory. In addition, the required performance level in each dimension would be defined to allow the ATM trajectory management and separation management to perform their functions, and for the airborne system to know whether or not it can comply. The performance would be specified as necessary to maintain efficiency and capacity – strict trajectory compliance is not necessarily implied.

Table 1-1 provides examples of trajectory characteristics that are in use in current operations within the NAS:

**Table 1-1. Trajectory Characteristics Addressed in Current Operations**

| | Intended trajectory | Window | Performance |
|---|---|---|---|
| Lateral (2D) | Leg Types (Track-to-Fix, Radius-to-fix) | Leg Types (no flexibility), fly-by turn transition area, holding patterns | RNP designation |
| Vertical | Assigned altitudes, descent/climb rates, approach glidepath | Assigned altitudes (no flexibility), minimum en route altitude, at-or-above altitudes, at-or-below altitudes, altitude windows | Implicit (e.g., certification and operational requirements for barometric altimetry) |
| Time (along path) | Speed assignment | Speed assignment (no flexibility), speed restrictions | Implicit |

In typical current operations, the concept of a changeable lateral window is not defined. The window for the lateral path is simply the intended lateral trajectory itself, as current separation is accomplished primarily in the lateral dimension using current-time information for same-level traffic. It is natural that the dimension that is most constrained is that which is graphically displayed to the controller and used as one of the means of achieving safe separation. One exception is a lateral window in current operations that may be found in the lateral fly-by transition, where a window of airspace is reserved around the turn point to allow for a variation of path location relative



to the transition waypoint due to speeds or other constraints of the aircraft systems. This window is collapsed to zero through the use of the RF transition in RNP operations. An example of a vertical window might be an assigned altitude change, assigned tactically, or a "between" altitude constraint defined in association with a published route or procedure. Of all the dimensions, time is currently the least constrained: it is addressed only through speed assignment to maintain separation tactically, propagating the current aircraft position in lateral dimension forward for a short period of time.

As these concepts are evolved, separation might become more strategic, using the intended trajectories to avoid conflicts between aircraft, and it could become more integrated across all dimensions. It is important to challenge conventional notions of how these trajectories are managed. First, adjustment of trajectory parameters to address system demand (paths, windows, performance required) could apply to the full trajectory, from origin to destination. This is because some aircraft will be actively controlling to the known and negotiated intended trajectory over its full length, compensating for disturbances to remain within its windows and performance bounds. For those aircraft that cannot control to the intended trajectory, larger tolerances for prediction and less stringent requirements will be used. The control aspect of the negotiated trajectory extends the time horizon of predictability for aircraft that actively control to it, within definable tolerance, all the way to the destination airport in current FMS equipped airplanes, but the method will equally apply to lesser equipped aircraft; the available performance limits will just not be as high. When upsets like weather occur, the trajectories could be moved through a process of renegotiation where, once complete, the time horizon of predictability might again be the destination.

Within NextGen, lateral trajectory windows could have utility for unmanned aircraft or as a means of accommodating special use airspace (which is a lateral window for the operations being conducted therein). They also would have utility to provide flexibility for aircraft to divert around convective weather, or to enable path contraction or expansion as a means of ensuring better time-of-arrival control at a merging point. Lateral trajectory windows can be a valuable tool to the ANSP. If they are geographically specified, they could be moved to avoid constraints such as weather, with the trajectory redefined within the relocated window. They could also be reduced in size at the same time, if necessary, to allow for higher density of operations.

Similarly, the time dimension could use more explicit definition. It is commonly recognized that a RTA at the final traffic merge point (e.g., approach intercept or the runway threshold) could be an important part of improving the sequencing of arrival flows during near-capacity operations. However, the ETAs of a negotiated trajectory could be as effective in merging and sequencing provided they are accurate. If accurate ETA information from highly equipped aircraft is available, it could be analyzed relative to each other at common points (merges) or on common paths (spacing) to handle multiple aircraft throughput. In the

event some ETAs do not allow for the planned operation, assignment of an RTA could be used to resolve the issue as a last resort.

When all four dimensions are considered, the relationship between the types of windows becomes more apparent. If the lateral and vertical windows are completely constrained, the time of arrival of any crossing traffic must also be completely constrained in order to maintain separation. An analogy can be found in automobile traffic, where the lateral path is constrained by the roads and traffic lights control crossing times where roads intersect. However, if flexibility is given in at least two dimensions, it may be possible to maintain more efficient traffic flows by allowing each aircraft some flexibility to account for changes in the airspace, the weather, or other traffic. This is commonly accomplished in today's operations through the flexibility of vertical (altitude assignment) and time (speed assignment). Within NextGen, flexibility in the lateral dimension should also be considered in the same way that two cars driving across a parking lot can avoid each other with minor changes in their path and without altering their speed. The complete trajectory object for NextGen must be defined in the near-term, as it can affect multiple aircraft systems and ANSP systems. Key attributes that need to be addressed include:

1. _Lateral windows:_ These are not currently defined, with the exception of holding patterns and fly-by and fly-over turns.
2. _Vertical desired trajectories:_ Vertical trajectories are currently defined only by an AT altitude constraint to an AT altitude constraint, or by a flight path angle into a fix. Additional paths may be necessary depending on the required tolerances, such as the curved paths associated with idle descent and barometric vertical navigation.
3. _Vertical performance:_ Vertical RNP, to include altimeter errors as well as flight technical errors, would need to be developed. Vertical separation criteria between two aircraft in transition would also need to be studied and developed.
4. _Time:_ All three characteristics of time (trajectory, window, and performance) need to be developed.

While all achieved aircraft trajectories are in fact continuous (e.g., from departure gate to arrival gate), the trajectory object may only contain specific elements of the trajectory, with ground and airborne automation systems computing a continuous intent trajectory by using identical methods to fill the gaps. While the actual trajectory is only defined behind the aircraft, the intended trajectory is only useful in front of the aircraft, and a trajectory clearance may only cover a portion of the remaining flight. The trajectory object is a subset of the flight object, which will include all data associated with a particular flight within the ground automation systems.

## Appendix 2: Key Enablers

Each operational capability presented in this roadmap is associated with one or more changes that enable it. In this appendix, the key enablers are examined, with each key enabler denoting the operational capabilities it supports. As the roadmap has begun to establish the needed equipage, this appendix, at a high level, answers the question, what operational capabilities are associated with each key enabler. The key enablers are then described in terms of technology options to support that aircraft functionality. This allows a simple technical readiness review (red/yellow/green) expressed in terms of a stoplight chart. The notes section of the appendix recognizes future and emerging technology options. This allows both a gap analysis of roadmap readiness and a pointer to further standards and R&D work.

Future versions of the Avionics Roadmap will address expected performance levels for the various enablers, if they are not already specified or if changes to existing specifications are needed. This will, for example, require the specification of the level of functionality for the various operational capabilities that are enabled by ADS-B In. This specification of avionics performance level will require performance allocation for each operational capability between the aircraft, air traffic, and AOC elements. This allocation will be captured in this document and used to revise other NextGen planning documents.

It is also important to note that the Avionics Roadmap does not convey how certain changes (enablers) would be implemented (voluntary action, incentives, mandates, or other means). It is recognized that the FAA is in the midst of proposed rulemaking for ADS-B Out, and this roadmap specifically recognizes the operational capabilities that both ADS-B Out and ADS-B In can support. Future versions of this roadmap will reflect FAA decisions regarding required ADS-B Out functionality and any impacts that these decisions may have on the aircraft operational capabilities presented in this document.

The Aircraft Working Group (AWG) invites comment on this work, especially in the area of functional allocation. As we look at the roadmap, are there other simpler ways to accomplish the required operations? Additionally, how should this functionality be allocated?

**Table 2-1. Technology Options for Positioning Key Enablers (Mid-Term)**

| Key Enabler Operational Capabilities | Technology Options to Achieve Key Enabler Aircraft Functionality<br>(Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| GNSS<br>SAFE-007<br>SAFE-008<br>LV-004 | For Technical Standard Order (TSO) C129: GNSS source for FMS / or /<br>Stand-alone GNSS receiver/navigator<br>For TSO-C145/146: GNSS source for FMS / or /<br>Stand-alone GNSS receiver/navigator | Future technology options may include:<br>GBAS I, GBAS III, Ground-based Regional Augmentation System (GRAS),Global Positioning System Level 5 (GPS L5), Global Navigation Satellite System (GLONASS), Galileo |

| Table 2-2. Technology Options for Communications Key Enablers (Mid-Term) | | |
|---|---|---|
| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/ Notes |
| Initial Data Link (FANS 1/A+)<br>SAFE-002<br>SAFE-006<br>PRP-006<br>NT-001<br>NT-002<br>NT-004<br>NT-005<br>NT-006<br>NT-007<br>DS-002<br>ATM-001<br>ATM-002<br>ATM-004 | Oceanic & Accommodated Domestic<br>* Oceanic: RTCA Document (DO)-306 / DO-258A<br>* Domestic: DO-290/2 / DO-305<br>Components involved:<br>* Cockpit display (HMI)<br>* FMS (application hosting)<br>* CMU (routing)<br>* Oceanic: VHF / SATCOM (subnet)<br>* Domestic: VDR (subnet) | Forward fit to migrate to FANS 2/B; current fleet to be accommodated. |
| Initial Data Link (FANS 2/B)<br>SAFE-002<br>SAFE-006<br>NT-002<br>NT-004<br>NT-005<br>NT-006<br>DS-002<br>ATM-001<br>ATM-002<br>ATM-004 | Domestic Data Link with no limitations<br>* DO-290/2 / DO-280B<br>Components involved:<br>* Cockpit display (HMI)<br>* FMS (application hosting)<br>* CMU (routing and application hosting)<br>* Oceanic: ACARS / SATCOM (subnet)<br>* Domestic: VDR (subnet) | Current fleet to migrate to LINK Post Pioneer ATN Baseline 1 upon European Union implementing rule target date |

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| Initial Data Link (ATN Baseline 1 LINK Post Pioneer)<br>SAFE-002<br>SAFE-006<br>NT-002<br>NT-004<br>NT-005<br>ATM-001<br>ATM-002<br>ATM-004 | Domestic Data Link with no limitations<br>* DO-290/2 / DO-280B<br><br>Components involved:<br>* Cockpit display (HMI)<br>* CMU (application hosting & routing)<br>* FMS (Integration or application hosting)<br>* VDR (subnet) | Forward fit to migrate to Initial ICAO Compliant CPDLC or Extensions to ARINC 623 |
| Data Link (Integrated with FMS or stand-alone navigator, and not supported by Initial Data Link enablers)<br>PRP-004<br>PRP-005 | RTCA Special Committee (SC)-214 | Presumes integration with FMS or stand-alone navigator. Not supported by initial CMU-based enablers. |
| Data Link (Not Supported by Initial Data Link Enablers)<br>SAFE-002<br>SAFE-007<br>NT-008<br>NT-009<br>ATM-003<br>ATM-005<br>ATM-006 | SC-214 | |

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| ADS-C<br>PRP-006 | Oceanic & Accommodated Domestic<br>* Oceanic: DO-306 / DO-258A<br>* Domestic: DO-290/2 / DO-305<br><br>Components involved:<br>* Cockpit display (HMI)<br>* FMS (application hosting and integration)<br>* CMU (routing and application hosting)<br>* Oceanic: VHF / SATCOM (subnet)<br>Domestic: VDR (subnet) | Forward fit to migrate to Converged FANS / ATN ADS-C; current fleet to be accommodated. |

**Table 2-3. Technology Options for Surveillance Key Enablers (Mid-Term)**

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality<br>(Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/ Notes |
|---|---|---|
| ADS-B Out<br>PRP-007<br>DS-008<br>DS-009<br>NT-003 | UAT<br>Or<br>1090ES Out | ADS-B NPRM proposes<br>ADS-B Out mandate based on airspace classification and 1090ES<br>ADS-B Out mandate for FL240 and above |

**Table 2-4. Technology Options for Trajectory Management Key Enablers (Mid-Term)**

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options Notes |
|---|---|---|
| RNAV<br>PRP-002<br>PRP-003<br>NT-001<br>NT-002<br>NT-004<br>DS-001<br>DS-002 | FMS with RNAV Input (as required)<br>Or<br>Stand-alone GNSS receiver/navigator with RNAV (As required) | RNAV 1 for terminal operations;<br>RNAV 2 for en route operations |
| RNP<br>SAFE-001<br>PRP-001<br>PRP-003<br>PRP-004<br>PRP-005<br>DS-006 | Position Source for FMS with RNP as Required by Procedure / OR / Stand-alone GNSS receiver/navigator with RNP as required by procedure | As required by procedure |
| RNP 10 | Position Input to FMS as required / OR / Stand-alone GNSS C129 Navigator | |
| RNP 4<br>PRP-006 | Position Input to FMS as required / OR / Stand-alone GNSS C129 Navigator | |
| RNP 1 | Position Input to FMS as required / OR / Stand-alone GNSS receiver/navigator with RPN 0.3 | |
| RNP 0.3 | Position Input to FMS as required / OR / Stand-alone GNSS receiver/navigator with RPN 1 | Capability to fly procedures with RF Legs |
| RNP-2 | Position Source for FMS with RNP-2 / OR / Stand-alone GNSS receiver/navigator with RNP-2 | See AC 90-RNP |

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| RNP SAAAR<br>PRP-001<br>DS-006<br>DS-007<br>DS-010<br>LV-001<br>LV-002 | Position Source for FMS with RNP SAAAR authorization for aircraft and aircrew | |
| RF Leg Capability<br>PRP-001 | FMS w/ RF Leg Capability as Required by Procedure / OR / GNSS Navigator with RF Leg Capability as Required by Procedure | |
| VNAV<br>PRP-004<br>PRP-005 | Baro or Geometric Capable FMS / OR / GNSS Stand-alone Navigator | Advisory vs. coupled VNAV |
| Vertically guided RNP<br>PRP-005 | TBD | |
| CTA<br>NT-005<br>NT-006<br>NT-007 | CTA-capable FMS / OR / CTA-capable stand-alone GPS navigator | |
| D-Taxi | TBD | Integration with data link and other systems not defined |

**Table 2-5 – Technology Options for Displays Key Enablers (Mid-Term)**

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| CDTI<br>SAFE-005<br>PRP-006<br>DS-001<br>DS-002<br>DS-003<br>DS-004<br>DS-005<br>DS-006<br>DS-007<br>DS-008 | Class 2 or Class 3 EFB / OR / EFIS-Based CDTI / OR / Stand-alone MFD with CDTI | Application-specific (e.g., no airborne ADS-B apps on Class 2 EFB) |

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| DS-009<br>DS-010<br>LV-003<br>LV-004 | | |
| CDTI with Alerting<br>SAFE-005 | TBD | |
| Guidance Display<br>DS-009 | TBD | |
| Moving Map<br>SAFE-002<br>SAFE-003<br>SAFE-005 | Class 2 or Class 3 EFB / OR / EFIS-Based MFD / OR / Stand-alone MFD | |
| EFVS<br>LV-001<br>LV-002<br>LV-003<br>LV-004 | EFVS system with operational credit | |
| SVS<br>LV-001<br>LV-002<br>LV-003<br>LV-004 | SVS system with operational credit | |

**Table 2-6 – Technology Options for Safety Enhancements Key Enablers (Mid-Term)**

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| Aircraft Characteristic Database<br>SAFE-007<br>SAFE-008 | TBD | |
| Aircraft Wake Database<br>SAFE-007<br>SAFE-008 | TBD | |

| Key Enabler Operational Capability | Technology Options to Achieve Key Enabler Aircraft Functionality (Green = Available; Yellow = Under Development; Red = Not Yet Defined or Not In Development for Use) | Future/Emerging Technology Options/Notes |
|---|---|---|
| FIS-B<br>SAFE-002<br>SAFE-006<br>PRP-006<br>ATM-004 | UAT-based FIS-B / OR / Satellite-Based FIS / AND / Moving Map/Multi-Function Display with Available Positioning Source | |
| TAWS Enhancements<br>SAFE-001 | TBD | |
| TCAS Enhancements<br>SAFE-004 | TBD | |
| Enhanced MDCRS Sensors<br>ATM-006 | TBD | |
| Improved Terrain Database<br>SAFE-001<br>SAFE-003 | TBD | |
| Improved Obstacle Database<br>SAFE-003 | TBD | |

## Appendix 3: Work Deferred to the Far Term

Appendix 3 of the previous Avionics Roadmap contained a list of omitted operational improvements (OIs) that did not appear to be ready for incorporation under the six capability areas, even though they were thought to have a role related to aircraft avionics. These OIs were referred to in the appendix as Deferred OIs. In some cases, deferment happened because the OI was thought to not be applicable through the mid-term, while in other cases, deferment happened for lack of sufficient information to evaluate the feasibility of the OI. Since the publication of ARM-1, not only has more information been obtained to evaluate these OIs, but in addition, the IWP has been modified to make many of the OIs on the deferred list into Enablers. For these reasons, the list of OIs deferred for discussion to the initial version of the Avionics Roadmap was revisited to create this new appendix. The new list incorporates both OIs and ENs and includes mid-term as well as far-term work.

Table 1 lists the deferred OIs and ENs that are thought to be related to the charter of the JPDO Aircraft Working Group. Since not every aspect of the work required to fulfill the object of a particular OI or EN is related to the aircraft, Table 1 identifies the specific elements that relate to aircraft. To a large extent, much of this work in some way relates to avionics upgrades of one form or another, and includes not only navigation system electronics, but also electronic sensors, cockpit displays, and aircraft information systems.

**Table 1 – Listing of deferred far-term work and relationship to the aircraft.**

| IWP OI # or EN # | Title | Relationship to Aircraft |
|---|---|---|
| **OI-0340** | Near-Zero-Visibility Surface Operations | Aircraft need equipment to support operation at airports in near-zero/zero visibility conditions. The minimum level of equipage will vary depending on the operational expectations and performance improvements : enhanced situation awareness, taxi assistance or even taxi guidance. Such equipage requirements may also be required to all ground support vehicles operating in the aircraft operation area (AOA). May include moving map displays, runway proximity alerting, preferred exit indications, runway overrun protection and possibly break to vacate, Cockpit Display of Traffic Information (CDTI), uplink taxi route, accurate navigation equipment, enhanced vision sensors, synthetic vision systems, cooperative Automatic Dependent Surveillance-Broadcast (i.e., ADS-B out) for aircraft and ground vehicles, and on-board synthetic and enhanced vision systems. |
| **OI-0341** | Limited Simultaneous Runway Occupancy | Runway capacity is increased through the allowance of more than one aircraft on the runway for specific situations (e.g. one aircraft can enter the runway while another aircraft is departing.) The minimum level of equipage will vary depending on the operational expectations and performance improvements. Aircraft may require moving map displays, runway proximity alerting, Cockpit Display of Traffic Information (CDTI), uplink taxi route, cooperative Automatic Dependent Surveillance-Broadcast (i.e., ADS-B out), and perhaps precision surveillance equipment and very accurate prediction and adherence to 4-Dimensional Trajectory (4DT) (air and ground). It may also be required that information provided to the aircraft be synchronized with ANSP and ground ops displays as well. |
| **OI-0354** | Reduced Oceanic Separation – Co-Altitude Pair-wise Maneuvers | Aircraft equipment required to support better communication between planes to maintain safe separation distances. Depending on the implementation chosen, this could involve Automatic Dependent Surveillance-Contract (ADS-C)possibly with prediction and transmission of 4-Dimensional Trajectory (4DT), Automatic Dependent Surveillance-Broadcast [ADS-B] out and in with ITP capability, RNP, and satellite-based voice and data communications, as well as TCAS adjustment., and satellite-based voice and data communications. In addition, the "co-altitude pair-wise maneuvers" will require in-flight data links between adjacent aircraft to communicate flight critical control information to coordinate intended maneuvers. |

| IWP OI # or EN # | Title | Relationship to Aircraft |
|---|---|---|
| **OI-0362** | Self-Separation - Self-Separation Airspace | Aircraft must meet equipage requirements to enter self-separation airspace, including transmission of trajectory intent information through cooperative surveillance. Transition into self-separation airspace includes an explicit hand-off and acceptance of separation responsibility by the aircraft. Depending on the implementation chosen, this could involve Automatic Dependent Surveillance-Contract (ADS-C) possibly with prediction and transmission of 4-Dimensional Trajectory (4DT), Automatic Dependent Surveillance-Broadcast [ADS-B] out and in with ITP capability, RNP, and satellite-based voice and data communications, as well as TCAS adjustment. |
| **OI-3104** | Enhanced Safety of Airborne Systems | Aircraft reliability and airworthiness are improved through equipping aircraft, in addition to current equipage, with systems and sensors to enable integrated vehicle health management, cockpit display of up-linked weather information, detection and alleviation of turbulence and gust, detection of icing conditions on aircraft and engines, and prevention or mitigation of wake vortex upset, as well as data monitoring and recording. A number of enablers below support this OI. |
| | | |
| **EN-2070** | Aircraft Systems - Aircraft-Aircraft Hazardous Weather Information Sharing | Equipage of aircraft with advanced air/air or air/ground/air data communication avionics to transmit hazardous weather information between aircraft or from aircraft to ground and then up to all aircraft. |
| **EN-2810** | Aircraft Systems - Turbulence Mitigation | Equipage of aircraft, in addition to current equipage, with on-board turbulence and gust detection and alleviation systems. |
| **EN-2820** | Aircraft Systems - Icing Alleviation | Equipage of aircraft with icing detection and alleviation systems for aircraft surfaces and engines, including both in-flight icing detections and identification of potential icing conditions within aircraft operating environment. |
| **EN-2840** | Aircraft Systems - Vortex Avoidance Alleviation | Equipage of aircraft with onboard systems to detect, predict, and mitigate inadvertent wake vortex encounters. |
| **EN-3056 EN-3057** | Vehicle Systems Health Management, Levels 1, 2 | Equipage of aircraft with on-board systems and sensors to detect and diagnosis sub-system failures. These systems provide a reasoning system and output either cockpit alerts or send information to ground-side dispatch and maintenance. These systems will also enable continuing monitoring of aircraft operations within various operational environment of 4DT, identifying system/subsystem anomalies, and taking proper preventive actions when necessity arises. |
| **EN-3113** | Improve Reliability and Airworthiness of Aircraft | Equipage of aircraft with improved control, avionics, and information management systems to reduce system failures and lost missions. Also includes improving long-term structural airworthiness using new materials and advanced designs. |

| IWP OI # or EN # | Title | Relationship to Aircraft |
|---|---|---|
| **EN-3126** | Aircraft Upset Prevention and Recovery | Equipage of aircraft with upset control guidance and control countermeasures. In-flight upsets in the TBO and 4DT operational environment need to be studies, i.e. while increasing capacity and efficiency, potentials of increased in-flight upsets due to wake vortex or turbulence encounters need to be studies, and proper equipage of aircraft may be required to avoid encounters and better flight controls to assist pilot in the recovery process. |
| **EN-3127**<br>**EN-3128** | Reduce Airborne Icing-Related Incidents, Lev 1, 2 | Equipage of aircraft with icing detection and avoidance technologies. |

## Relationship to ARM Capability Groups

The far-term work cited in Table 1 can nearly all be related to one of the six NextGen operational capability groups previously defined above and discussed earlier in this document. This relationship is shown as follows:

- **Safety Enhancements, Hazard Avoidance, and Mitigation -**
  - OI-3104: Enhanced Safety of Airborne Systems
  - EN-2070: Aircraft Systems - Aircraft-Aircraft Hazardous Weather Information Sharing
  - EN-2810: Aircraft Systems - Turbulence Mitigation
  - EN-2820: Aircraft Systems - Icing Alleviation
  - EN-2840: Aircraft Systems - Vortex Avoidance Alleviation
  - EN-3126: Aircraft Upset Prevention and Recovery
  - EN-3113: Improve Reliability and Airworthiness of Aircraft
  - EN-3127 : EN-3128 Reduce Airborne Icing-Related Incidents, Lev 1, 2
  - EN-3056: EN-3057 Vehicle Systems Health Management, Levels 1, 2
- **Published Routes and Procedures -**
  - OI-0354: Reduced Oceanic Separation – Co-Altitude Pair-Wise Maneuver
  - OI-0341: Limited Simultaneous Runway Occupancy
- **Negotiated Trajectories:**
- **Delegated Separation:**
  - OI-0362: Self-Separation - Self-Separation Airspace
- **Low Visibility/Ceiling Approach/Departure and Taxi -**
  - OI-340: Near-Zero-Visibility Surface Operations
- **ATM Efficiencies:**

In veiwing this list, and considering the aircraft role identified in Table 1, it can be seen that the role of the deferred work cited in the first five categories generally involves upgrading aircraft avionics equipment to some extent. Some of these items, however, require aircraft-related work that lies outside of avionics. For example, EN-3056/3057 describes aircraft health monitoring systems, which may consist of both avionics to monitor aircraft operational performance under the NextGen TBO and 4DT operational environment and other electronic sensory systems to detect anomalies of the aircraft system, subsystems, structures, components, etc. to support preventive maintenance and/or repairs. The former may fall under the ATM and the latter under the safety enhancement. In either case, the definition of the capability area will require further clarification and more detailed requirements of the health and usage monitoring system enabler.

## Addressing Far-Term Deferred IWP Work in Version 2 of the Avionics Roadmap

The second version of the Avionics Roadmap will address the far-term avionics-related work identified in the IWP. For each capability area and deferred work item, the roadmap will seek to provide a clear understanding of what is in place today, what is committed and coming (per the NextGen Implementation Plan), and what are the benefits and business cases supporting the incorporation of these technologies into future aircraft.

In addition, it will also identify the unique technical challenging areas facing the industry while implementing the NextGen aircraft avionics. It will provide a reference to Government agencies and the industry in defining far-term R&D requirements. Although the research requirements identified will be focused on far-term aircraft avionics, they will provide linkages between these far-term avionics R&D requirements and the NextGen implementation plan schedule of far-term capabilities. They will examine technical issues of new equipage/avionics development and their implementation. These R&D efforts will bridge the FAA far-term R&D goals, as outlined in the FAA National Aviation Research Plan (NARP), and JPDO/AWG far-term aircraft avionics equipage requirements. They will also provide input on the FAA NARP yearly updates to ensure that the capabilities implemented by the FAA NextGen Implementation Plan are synchronized with the Avionics Roadmap or vice versa.

### Safety Enhancements, Hazard Avoidance, and Mitigation

There are several safety enhancements planned for the far-term that are aimed at improving the reliability and airworthiness of aircraft through upgraded avionic, information, and flight management systems. The following technologies (some already identified in version 1 of the ARM) include:

- Cockpit display of integrated weather information
- Avionics to enable remote activation of airborne sensors
- Avionics to transmit weather information to ground or other aircraft, and to receive it from the ground
- Airborne sensor systems for icing and turbulence detection
- Icing alleviation systems and sensors
- Avionic systems for wake upset control
- Vehicle health management systems

While it is possible that some of these technologies may be implementable near the end of the mid-term, many have slid into the far-term. Displays to integrate weather information and vehicle health management systems (e.g., Aircraft Condition Analysis and Management System (ACAMS)) to identify vehicle health problems have elements that can be fielded in the mid-term. Advanced monitoring systems will integrate information from various sensors to not only identify and mitigate sub-system failures but also to send information to dispatch and maintenance so that trends may be assessed to avert potential failures. The performance measure is reduced systems failures or reduced impact of those failures that occur. Other improvements, such as icing detection/mitigation systems and wake upset control, require extensive research and development. For these far-term technologies, planning is required to define the required research and development investments needed to support NextGen.

Version 2 of the ARM will present more information to better define the required avionic automation technologies for these systems and identify the operational benefits and costs. This assessment will consider several ongoing government research programs including the NASA Aviation Safety Intelligent Resilient Aircraft Control (IRAC) program, the Integrated Vehicle Health Management (IVHM) program, the Integrated Intelligent Flight Deck (IIFD) program and other FAA programs. This should allow an assessment of the feasibility and costs of these technologies, and determine the likely integration path with timeframes into NextGen.

Within the current IWP, the majority of the safety improvements fall under OI-3104 Enhanced Safety of Airborne Systems. This is an umbrella OI that is supported by a number of ENs that were themselves OIs in previous versions of the IWP. These ENs are EN-2070, EN-2810, EN-2820, EN-2840, EN-3056, EN-3057, EN-3113, EN-3126, and EN-3127.

### Published Routes and Procedures

Availability of user preferred oceanic profiles is further increased through reduction of horizontal spacing to below 30 miles for pair-wise co-altitude maneuvers between capable aircraft. Co-altitude maneuvers, such as passing a similar-speed aircraft, have much longer risk exposure times than altitude change maneuvers, resulting in higher collision risk, so communication uncertainties play a significant role in defining safe separation standards.

Avionics technology to enable reduction of horizontal spacing and allow in trail climbs/descents and co-altitude passing include ADS-C, ADS-B, RNP, and satellite-based voice and data communications. Coordination with the ANS Working Group will likely be needed to mature the details of this concept.

Upgraded avionics will be needed to allow increased airport throughput through the allowance of more than one aircraft on the runway for specific situations. One situation might be that an aircraft is allowed to land while another one is exiting to a taxiway; another situation could be that an aircraft can enter the runway while another aircraft is departing. Avionics would be required to facilitate close cooperation and sharing of information between pilots involved with these operations.

Version 2 of the ARM will present more information to better define the required avionic automation technologies for co-altitude maneuvering. An assessment of the technology readiness and likely implementation timelines will be obtained through evaluation of the work being performed in Surveillance and Broadcast Services (SBS) by the ADS-B Program Office. These timelines need to be consistent with the FAA NextGen Implementation Plan. A gap analysis will be conducted to ensure that these timelines that coincide with the capability implementation, or recommended changes to the implementation plan, are provided.

## Delegated Separation

The intent to make aircraft capable of separating themselves from one another can be fulfilled in large part by equipping the aircraft with avionics to transmit trajectory intent information and to provide cooperative surveillance with other aircraft. Self-separating aircraft avionics will need to execute standardized algorithms to detect and provide resolutions to conflicts. The avionic technologies that may be utilized to achieve self-separation include:

- Cooperative surveillance avionics via ADS-B Out
- Avionics to detect airspace boundaries
- Traffic collision and avoidance avionic displays
- Avionics for Airborne Merging and Spacing
- Avionics for air-ground data exchange
- Avionics for runway intrusion alerts
- Precision surveillance and situational awareness avionics

ARM version 2 will seek to provide further definition of the technologies and concepts needed to enable self-separation. The intent is to evaluate the maturity, readiness, and cost of the best solutions. An assessment of the technology readiness and likely implementation timelines will be obtained through evaluation of the work being performed in SBS by the ADS-B Program Office and the NASA 4D Airborne Separation Assurance Systems (4DASAS) research program.

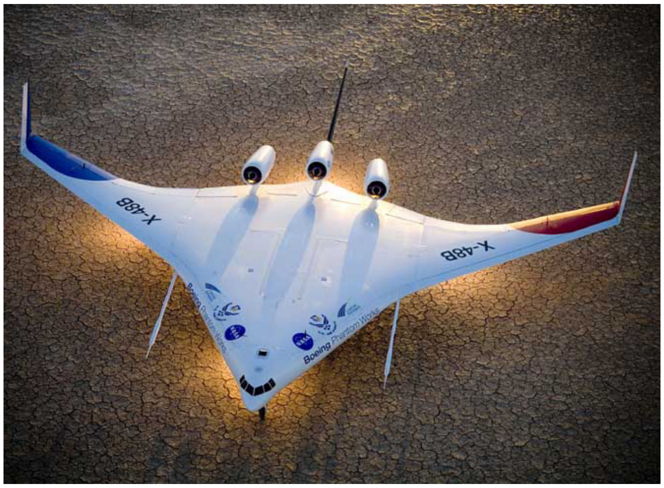
## Aircraft Systems for Low Visibility Alleviation

Low Visibility Surface Operations is one of the six capability areas identified in the ARM. As this topic area continues to be defined, the contribution of the roadmap will be to identify the on-board vision display requirements to allow VFR-style operations in near-zero visibility conditions. The technologies likely to be used are:

- ADS-B (Out & In)
- Cockpit Display of Traffic Information (CDTI)
- Ground Support Equipment (GSE) Cooperative Surveillance System (CSS)
- EVS/SVS for low/zero visibility conditions
- Uplink taxi route
- Improved accuracy navigation equipment
- Cooperative ADS-B Out for aircraft and ground vehicles

A key aspect in defining the required avionics requirement will be to research the best division of responsibility for maintaining separation. The specification of which tasks will remain human operator responsibility largely determines the automation level required of the avionics. The minimum level of equipage will vary depending on the operational expectations and performance improvements: enhanced situational awareness, taxi assistance, or even taxi guidance. An important aspect that needs to be considered is the amount of situational awareness that avionics can provide to allow for the ground maneuvering of aircraft.

Version 2 of the ARM will present more information to better define the minimum required avionic automation technologies, including the role of moving map displays, CDTI, ADS-B, cooperative surveillance (i.e., ADS-B Out) for aircraft and ground vehicles, and on-board synthetic and enhanced vision systems. Consideration of the likely implementation costs of various technologies should be considered also, depending on the operational expectations and performance improvements. The desired result is a list of recommendations to direct JPDO, FAA, and/or NASA research programs to better define and mature the best concepts.




# Appendix 4: Risks and Benefits Assessment of the Roadmap Operational Capabilities

## Introduction

The ordering of changes leading to the NextGen is driven by the need to solve pressing problems and constrained by maturity and development and implementation timelines. Priorities for the Avionics Roadmap development, based on an initial assessment of benefits and risk, are grouped as top-priorities for mid-term implementation and top priorities for research that will lead to mid- or long-term implementation.

The next steps that can be taken toward NextGen are for mid-term implementation. Top priorities are those that provide quantified high benefit by solving pressing problems and are low risk because they have matured through significant development—with understood avionics and ANS systems and procedures.

To facilitate further evaluation and emergence of aviation community consensus, this Avionics Roadmap proposes top priorities derived by a transparent data-driven assessment, intended to be updated as new information becomes available. A joint industry/government team of operators, engineers, and analysts developed the assessments, representing JPDO's Aircraft, ANS, and Safety working groups and the Interagency Portfolio and System Analysis divisions. The Benefits and Priorities Appendix lists key challenges and problems that have been identified by the JPDO, quantifies the benefit of proposed high priority capabilities, characterizes risks, and identifies the priority assessments for the Avionics Roadmap.

The initial assessment of benefits and risks is being used to guide maturation of the roadmap. Emphasis will be given to the capabilities noted below in terms of identifying improved interface and integration of work between the JPDO's Aircraft Working Group and other groups and organizations involved in work related to these capabilities. By putting emphasis (priority) on these areas, it is recognized that the right decision for NextGen will come from merging multiple perspectives – this roadmap provides an initial aircraft perspective.

Overviews of the proposed capabilities and associated key Enablers are provided earlier in this document. Grouped here by the key problems they address and the affected aircraft, these proposed top priorities for mid-term implementation shown in the table below:

| Problem | Who | Capability (Key Enabler) |
|---|---|---|
| **In busy metropolitan areas, airport flows interfere, constraining throughput** | Aircraft in Select High Density Airspace | PRP-002 Integrated Arrival/Departure Management (Area Navigation *(RNAV)*) |
| | Aircraft in Select High Density Arrival / Departure Airspace | PRP-001 2D RNP with Curved Segments – Reduce Lateral Track Spacing using RNP *(RNP Arrival/Departure with Radius-to-Fix (RF) Legs)* |
| **Limits on sector capacity due to complexity and workload** | Aircraft in High Density Airspace | ATM-002 Data Link En Route Clearance Delivery and Frequency Changes *(Initial Data Communications)* |
| **Safety, [security and national defense (not addressed)] must be sustained or improved**<br>*Reduce runway incursions* | Aircraft at High Density Airports | SAFE-005 Surface Collision Avoidance: Aircraft-based *(Surface Moving Map with Own Ship, Display of Traffic, and Advisories)* |

| Problem | Who | Capability (Key Enabler) |
|---|---|---|
| *Increase safety and reduce transgressions into restricted airspace* | Any; Primarily Small Aircraft | NIP – On Demand NAS Information, SAFE-002 Weather Avoidance, SAFE-002 Weather Avoidance, SAFE-006 Airspace Avoidance, Traffic Display<br>*(Flight Information Services – Broadcast (FIS-B) & Display of Traffic)* |
| SAFE-006 Airspace Avoidance, Traffic Display | | |
| (Flight Information Services – Broadcast (FIS-B) & Display of Traffic) | | |
| **The total system must be economical** | Aircraft over Gulf of Mexico | PRP-007 Reduced Oceanic and Non-Radar Separation (Gulf of Mexico)<br>*(Automatic Dependent Surveillance – Broadcast (ADS-B) Out for Non-Radar Separation)* |
| | Aircraft at High and Moderate Density Airports | NT-003 Initial Surface Traffic Management *(Air Traffic Management and Ramp)* |

A further step that can be taken toward NextGen is for the early completion of research that leads to mid-term or far-term implementation. Grouped by the problems they solve and the affected aircraft, the proposed key types of improvements or alternatives, and the issues that must be resolved shown in the table below:

| Problem | Who | Capability | Selected Issues |
|---|---|---|---|
| **Inability to fully utilize individual runway capacity** | Aircraft in High Density Airports | CDTI-Assisted Visual Separation (CAVS) in Marginal Meteorological Conditions (MMC) conditions<br>DS-008 Enhanced Visual Approach (MMC-Certified CAVS) | The cost factor is still very much in question.<br>Maturity of technical requirements.<br>Level of aircraft equipage / participation necessary to realize benefits.<br>Lead time needed for avionics development and implementation. |
| | | DS-009 ADS-B Approach Spacing<br>(IMC-Certified CAVS) | Policies, procedures, and roles are uncertain and have significant associated risk. |
| **Inability to fully utilize individual runway capacity**<br>**(When closely-spaced to an active parallel runway)** | Aircraft on Select Close Parallels | Improved analysis and operational experience with parallel ILS approaches are used to update independent parallel approach criteria | Achievable runway spacing needs to be determined based on data and analysis |
| | | Use of precision navigation in combination with ADS-B to keep aircraft in front of the wake vortex of a paired approach and to mitigate against potential blunders. | Requirements for navigation and surveillance need to be determined. |



| Problem | Who | Capability | Selected Issues |
|---|---|---|---|
| **In busy metropolitan areas, airport flows interfere, constraining throughput** | Aircraft in Select<br>Hi-Density Airspace | PRP-001 Reduce Lateral Track Spacing Using RNP | How close is close enough? Is ADS-B required to get the desired benefits? |
| | | Enhanced Metering, Sequencing and Spacing:<br>NT-005 Route Clearance with Required Time of Arrival (RTA)<br>NT-006 Route Clearance with RTA and Downlink of Expected Trajectory<br>NT-007 Trajectory Clearance with RTA and Downlink of Expected Trajectory<br>NT-008 Airborne Lateral / Vertical / Time Clearances<br>LV-011 (Airborne) Merging and Spacing | Multiple ways of performing metering, sequencing, and spacing |
| **Safety, security, and national defense must be sustained or improved**<br>*Reduce runway incursions* | At High Density Airports | SAFE-005 Surface Collision Avoidance: Aircraft-based<br>(Surface Moving Map with Alerting and/or Taxi Path) | What are the avionics requirements to enable support for these higher-criticality functions?<br>What is the suite of solutions available for different types of airports? |
| *Improve overall safety as NAS utilization increases* | Aircraft in High Density Airspace | SAFE-004 Airborne Collision Avoidance to support NextGen operational capabilities | Operational performance parameters and requirements uncertain<br>Controller alerting and responsibility |
| **The total system must be economical**<br>*Excess fuel burn and pollution due to non-optimum descents* | Aircraft in High Density Arrival / Departure | Optimum Profile Descents in High-Density Traffic:<br>PRP-004 Optimized Profile Descents (FMS Only)<br>NT-007 Trajectory Clearance with RTA and Downlink of Expected Trajectory,<br>DS-002 Use Optimized Profile Descents (Flight Management System + Flight Data Management System) | Multiple ways of performing optimum profile descents |

## Methodology for Selecting the Items for High Priority Mid-term Implementation, and High Priority Research

The methodology employed to identify the high priority implementation and research objectives for the mid-term leveraged a rich set of data developed by the JPDO, various FAA program offices, and other aviation stakeholders. A team staffed with industry and government representatives whose perspectives encompassed aircraft operations, air navigation services, and regulatory oversight collected and evaluated the data.

Previously, the JPDO had undertaken a risk/benefit assessment (RBA) of a wide range of capabilities and their associated key enablers. A principal focus of the assessment addressed the range of benefit mechanisms accruing to aircraft operators, the public and the service provider. Quantitative analysis results of the operational effects of these benefit mechanisms were collected along with monetized benefit streams when available. Since the source analyses had been conducted at different times using a range of operational and economic assumptions, the results were normalized, when possible, to support a comparative assessment of the benefit contributions of the various capabilities.

Another consideration in the analysis was that capabilities were assessed pertaining to their maturity from policy, business, operational, and technical perspectives. Risks were identified with regard to the likelihood that the target capabilities could be implemented and business objectives achieved within the mid-term timeframe. While an explicit cost analysis for the key enablers was not done, cost considerations in terms of avionics affordability were taken into account.

The risk/benefit analysis entitled "Delivery of Prototype Risk Benefit Analysis System" was delivered to the JPDO in September of 2007 and contains:

- Spreadsheet tools
- Data sheets
- References
- A methodology paper
- A set of criteria for benefit and risk evaluation

Table 4-1 provides an assessment of all of the operational capabilities that are included in the roadmap. The table has the following information:

- **ID:** This refers to the operational capability (OC) number which is associated with the OC name.
- **Short Name:** This is a title descriptive of the OC. It also provides a list of related JPDO operational improvements (taken from the JPDO IWP) and items in the FAA's NextGen Implementation Plan.
- **Priority Action:** There are four categories of priorities associated with each operational capability.
  - NowGen activities: Activities that the FAA is committed to and implementing now.
  - Mid-Term Implementation Priorities: Recommendations of this roadmap for priority implementation of Operational Capabilities before 2018.
  - Priority Research: Activities that are not recommended for implementation by 2018, but research is justified to lead to implementation prior to 2025.
  - Roadmap Items: Items that are considered operational feasible prior to 2025 but did not make the priority list.
- **Overall Risk:** This is defined as high, medium, and low. Definitions of these risks are presented at the end of this appendix. The risk/benefit analysis has the risks broken into elements: Technical, Planning, Policy, Procedures and Institutional Risk, and Changes in Roles and Responsibilities. This was omitted from this document, and only the overall risk is provided. The reader can refer to the RBA source presented above for the details.
- **Overall Benefit:** This is defined as high, medium, and low. Definitions of these risks are presented at the end of this appendix. These benefits were divided into domains in the original risk benefit analysis, but this level of detail was omitted from this document. The reader can refer to the RBA source presented above for the details.
- **Comments:** The comments section summarizes the rationale for the risks and benefits and is often taken from the RBA analysis mentioned above or from other sources.
- **References:** There are three types of references. The first is defined as "RBA: title" where the information is derived from one of the data sheets associated with the RBA assessment. This is generally a 3-10 page paper that provides both qualitative and quantitative data on the rationale for evaluating the risks and benefits. The second reference is defined as RBA matrix, where there is no data sheet, but a summary of the rationale for the risks and benefits is presented in the spreadsheet tool. The third reference is specific citations. Where there is no RBA reference, this is new information that has been collected since the RBA work was done.

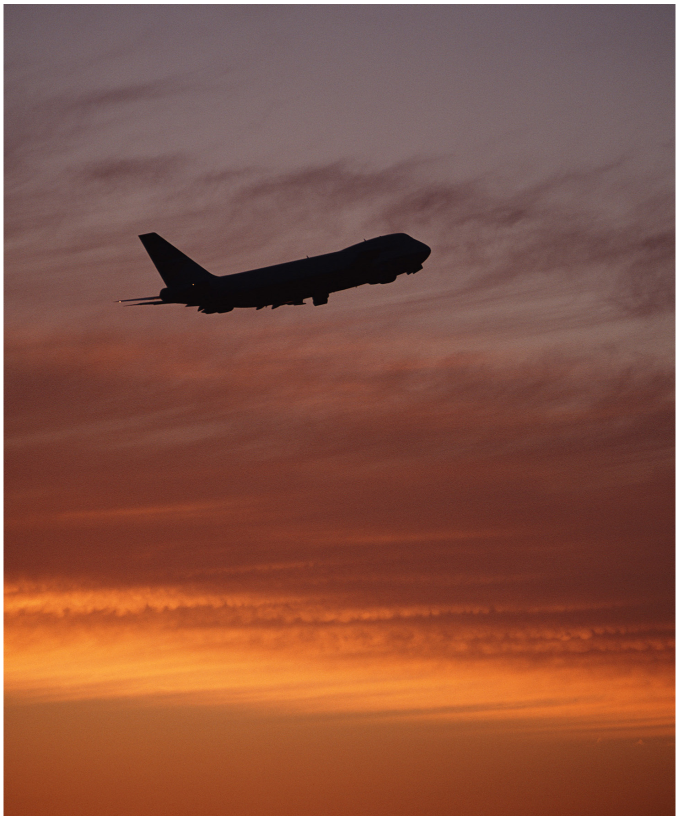
This information on risks and benefits was reviewed by a tiger team that was established by the Aircraft Working Group to develop priorities. The general principle used by the tiger team was to recommend items that were of low, and in a few cases moderate, risk and high benefit for mid-term implementation, and high risk and high benefit for priority research. However, there were other considerations that fed into the prioritization categorization, so there is not a one-to-one match between the risk benefit assessment and results. Table 4-2 presents cases where mismatches occurred.

The aviation community—working through a collaborative process—has identified a need for a series of near-term priority operational capabilities necessitating avionics investments. The FAA has committed itself to enabling these capabilities, as documented in the NextGen Implementation Plan.

The information that supported the priority assessment is presented in Table 4-2.

### Detailed Evaluation of the Mid-Term Implementation Priorities

For each of the recommended mid-term implementation priorities a more detailed assessment was performed and is in the tiger team report. An evaluation of each mid-term implementation recommendation is presented in Table 4-2. The table addresses the following questions/issues:



- What is the operational problem the capability solves? The range of problems included safety, throughput, capacity, and efficiency.
- What is the operational benefit? How the benefit is realized, how are the operational benefits quantified, and what is the data-driven confidence level for the benefit? Results for the high priority implementation recommendations are documented in Tables 4-3 through 4-8.
- What avionics, ground system, and/or procedure key enablers are required to realize the operational benefit? Key enablers for the high priority implementation recommendations are documented in Appendix 2: Key Enablers.
- Are those avionics, ground system, and/or procedure key enablers consistent with end-state designs and applications?
- What is the state of maturity for the target capability and its associated key enablers?
    - Is the operational concept complete and does it have some level of acceptance in the avionics community?
    - Have the operational and technical standards for avionics been finished? If so, what are they? If not, what activities are underway or need to be initiated to complete them?
    - Have the operational and technical requirements for ground systems been defined? If not, what activities are underway or need to be initiated to complete them?
    - Have the operational procedures for flight crews and controllers been defined? If not, what activities are underway or need to be initiated to complete them?
    - Has an initial operational capability for avionics been achieved?
    - Has an initial operational capability for ground systems been achieved?
    - What, if any, policy decisions are needed to realize the capability? If needed, when are those policy decisions required?
    - While an explicit cost analysis for the key enablers was not done, cost considerations in terms of avionics affordability were taken into account.

## Risk and Benefit Assessment Criteria

**Benefits:** Benefits were quantified, when possible, and were mostly extracted from already available documentation. When there was quantitative information, NAS-wide benefits of $100 million or more annually are considered to be high benefits, while medium benefits were considered to be between $10M-$100M annually, and low benefits were considered to be below $10M annually. If there is an application that is not NAS-wide, and there is evidence that individual carriers are considering or implementing the application, the application is considered to be high benefit. Also, benefits that significantly improve safety were also considered to be a high benefit, regardless of economic value. There are cases where the benefits were considered high if the users have expressed significant interest in this capability, but the dollar value did not exceed the $100M. For priority research items, there is often not adequate quantification of the benefits, but based on judgment about the operational concept, the authors postulated that the benefits could exceed $100 M per year.

**Risk Assessment:** The risk assessment methodology is presented below.

Next Generation Air Transportation System
Joint Planning and Development Office

### Risk Assessment Methodology from the PMD/RBA*

Risks are assessed based on *residual* risk after mitigations that are in hand are applied, and should reflect either current (not yet mitigated) risk levels or the difficulty for providing the additional needed mitigation. **Overall Risk** is assessed based on the levels of the four component risks. It should be the worst preponderance of the sub-ratings; it may be better than no more than one sub-rating and no more than one degree except that plan and PPI count as one. The sole other exception is that a high PPI risk due solely to institutional issues is not considered a "show stopper" for implementation, as this is deemed to be within JPDO's range of influence to resolve.

| PPI | Policy | Procedures | Institutional |
|---|---|---|---|
| Green | Low – No change in policy or no policy needed | Low – Procedures in place or have been developed | Low – Full agency and stake holders support; benefits aligned with required investment and control |
| Yellow | Medium – Policy resolution planned for a specific date | Medium – Procedures understood or in development | Medium – Misalignment between can and want to make it happen |
| Red | High – Controversial policy issue must be resolved | High – Procedures are undefined or major change from current procedures | High – Established lack of trust or entrenched positions exist |

| Technical Risk | |
|---|---|
| Green | Low – systems exist or standards exist |
| Yellow | Medium – systems proven in laboratory or operational test or standards being developed; development needed |
| Red | High – concept has not been proven or is not adequately specified or research is needed |

| Planning Risk | |
|---|---|
| Green | Low – program in place, resources adequate, and schedule is possible |
| Yellow | Medium – program not in place or resources are not adequate but schedule is doable |
| Red | High – schedule is impossible even if resources would be available |

| Changing Roles | |
|---|---|
| Green | Low – Stakeholder still has same scope of responsibilities but may be done in new ways but no change in roles |
| Yellow | Medium – Significant changes in how responsibilities carried out or limited changes in roles |
| Red | High – Significant changes in roles |

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* _One Story Methodology v 0.1b+vk.ppt and _README - Instructions for Use.doc

## Table 4.1 Priority Assessments

| ID | New Short Name | Priority Action | Overall Risk | Overall Benefit | Comments |
|---|---|---|---|---|---|
| **Safety Enhancements/Hazard Avoidance & Mitigation** | | | | | |
| **SAFE-001** | **Enhanced Low Altitude Operations** | NowGen | L | M | This is operating in Alaska and uses RNP or WAAS. Benefits have not been quantified but for mountainous areas where VOR coverage is limited this provides a significant reduction in altitude and more airspace access. |
| | OI -3010 Reduced Controlled Flight into terrain | | | | |
| **SAFE-002** | **Weather Avoidance** | | | | |
| | Weather Avoidance (GA and via ADS-B link)<br>NIP: On-Demand information | MT Implementation Priority | L | H | SBS Program Office estimates FIS-B and ADS-B based traffic situational awareness will yield $1,673M (FIS-B) and $720M (Traffic) in user benefit between FY08-35. Risk is low because this has been demonstrated and operationally test in Alaska and on the East Coast of CONUS. |
| | Weather sensing and digital communications networks (broadcast and request/reply) | Roadmap | | | Not evaluated |
| **SAFE-003** | **Obstacle Avoidance** | Roadmap item | | | Not evaluated |
| | OI -3010 Reduced Controlled Flight into terrain | | | | |
| **SAFE-004** | **Airborne Collision Avoidance** | Priority Research | H | H | Many of the future NextGen concepts involve spacing aircraft much closer together than is currently done today and with today's collision avoidance system, this would result in far to many false alerts. Thus, a new airborne collision avoidance system is needed to enable many of the longer-term concepts to be implemented. |
| **SAFE-005** | **Surface Collision Avoidance** | MT Implementation Priority and Priority Research | | | |
| | Ground-based and On-board Runway situational awareness with ownship position and display of proximate traffic.<br><br>NIP: Provide full surface situation Information (FT) | MT Implementation Priority | L | H | Somewhere between 28-46% of runway incursion errors could be avoided if the pilots knew exactly where they were on the runway surface and some additional runway incursion errors could be avoided by having prxomate traffic displayed on this surface moving map. FAA is committed to implementing these capabilies and has concluded that the risks are low. |
| | OI-0332 Ground-based and On-board Runway Incursion Alerting Equipment | Priority Research | M | H | NASA's analysis indicates that nearly all runway incursion could be eliminated with display of taxi routing information, alerting of potential runway incursions and ownship position on the ruwnay. |
| **SAFE-006** | **Airspace Avoidance** | | | | |
| | Airspace Avoidance (TIS-B and FIS-B)<br>NIP: On-Demand NAS information (C-ATM) | MT Implementation Priority | L | H | SBS Program Office estimates FIS-B and ADS-B based traffic situational awareness will yield $1,673M (FIS-B) and $720M (Traffic) in user benefit between FY08-35. Risk is low because this has been demonstrated and operationally test in Alaska and on the East Coast of CONUS. |
| | Airspace Avoidance--Sending up information about airspace changes<br>OI-0366. Dynamic Airspace Reclassification<br>OI-0368. Flow Corridors - Level 2 Dynamic. | Roadmap item | H | L | The OIs ( OI-0366 and OI-0368) that deal with fully dynamic airspace configuration are presented as low benefit because there is no clear understanding of what the marginal improvement is over the limited dynamic capability. Also the risks are high because of the complexity of providing this dynamic information to pilots without major increases in avionic costs, managing fullhy dynamic changes and addressing environmental issues. |

| ID | New Short Name | Priority Action | Overall Risk | Overall Benefit | Comments |
|---|---|---|---|---|---|
| SAFE-007 | **Wake Avoidance & Mitigation: Combination Air and Ground** | Part of closely spaced parallel approaches | H | H | See issues of CSPA |
| SAFE-008 | **Wake Avoidance & Mitigation: Aircraft Based** | Roadmap item | H | unk | It is not clear after addressing wake issues with OC#009 and extending visual operations using ADS-B/CDTI what the marginal value of improving the aircraft will be to avoid wake. |
| | **Publish Routes and Procedures** | | | | |
| PRP-001 | **Reduce Lateral Track Spacing Using RNP** | MT Implementation Priority and Priority Research | | | |
| | 2D RNP with Curved Segments – 2-001 Reduce Lateral Track Spacing using RNP (RNP Arrival/Departure with Radius-to-Fix (RF) Legs) | MT Implementation Priority | L | H | CAASD estimate of benefits are in the 10's of millions per year. The risk is relatively low since avionics exists to perform these curved segment approaches but the standards still need to be developed and are in the process of being developed. |
| | OI-0348 Reduced Separation – High Density Terminal, Less Than 3 Miles | Priority Research | H | H | The major benefit associated with less than 3 nmi in the terminal area is that it has the potential to deconflict airspace which will permit the better utilization of existing runways and the expanded use of additional runways. Building additional runways can add capacity only if the airspace is deconflicted so that the aircraft have unrestricted access to these runways in a safe manner. The risks are high because obtaining separation distances of less than 3nmi requires major changes in procedures, avionics and increased levels of safety assurance. |
| PRP-002 | **Integrated Arrival/Departure Airspace Management** | MT Implementation Priority and NowGen | M | H | |
| | OI-0311 Enhanced Arrival/Departure Routing and Access | NowGen | L | M | There are many airports where increased used of RNAV is being implemented (NY Airspace, Houston, Chicago, etc.). This capability alone will provide improvement but is not judged as high until integration is done with other capabilities such as extending the terminal area, providing extension of 3 nmi separation as well as limited dynamic airspace flexibility which is defined in OC-PRP-002b) |
| | NIP: Integrated Arrival/ Departure Airspace Management (HD) | MT Implementation Priority | M | H | Enables more routes in congested airspace to meet demand and allow flexibility. Underutilized airspace can be used quickly and effectively to keep the system moving when other areas become busy or impacted by adverse weather. (Benefits are estimated at $4.5B through 2024 over 9 locations) [8] |
| PRP-003 | **Closed Loop Parallel Offsets for Time of Arrival Control** | Roadmap item | | | Not evaluated |
| | NIP: Three dimensional Path Arrival Management (3D PAM) demonstration at DEN | | | | |
| PRP-004 | **Optimized Descent Profiles (FMS Only)** | NowGen and Priority Research | | | |
| | OI-309 Limited Continuous Descent Arrival<br>NIP: Use Optimized Descent Profiles (FT)<br>NIP: Continuous Descent Arrivals at ATL a | NowGen | L | M | Today there are optimized descent profiles using RNAV-1 and VNAV at selected airports and these will be expanded to other airports in the future. To achieve higher benefits the capability will have to feasible at more airports with more complex traffic and higher densities. This is described in OC PRP-004b. |
| | OI-0330 Time-Based and Metered Routes with CDA<br>NIP: Tailored Arrivals at MIA (demonstrations) | Priority Research | H | H | It is clear from the analysis of Hahn and Hoffman (2007) that CDAs can be performed today in low density traffic or under special circumstances, but today there is no way to generically apply this procedure to medium or high-density airports without enhancements to ground or airborne capability. To achieve the higher density operations will require upgrades in avionics and considerably more research |

| ID | New Short Name | Priority Action | Overall Risk | Overall Benefit | Comments |
|---|---|---|---|---|---|
| PRP-005 | **3D RNP Arrival and Departure Operations** | Priority Research | H | H | Quantitative analysis has been been done on this capability but it is associated with the following taken from the two pagers "The required protected airspace would be reduced compared to today's operations. 3D RNP procedures could be designed with no level segments, thereby enabling a non-idle descent variation of a CDA. Alternatively, the procedure designer could create two sequential waypoints with the same altitude constraint which would require flights to level-off for proceduralizing separation, and the increased vertical predictability that 3D operations offer could allow for arrival and departure procedures to be placed closer together than in a vectoring or 2D RNAV environment. |
| PRP-006 | **Reduced Oceanic Separation– Altitude Change Pair-wise Maneuvers** | Roadmap item/ recommend that it be in priority implementation | M | H | A 2007 analysis by BAE Systems indicates that the user savings per aircraft could be around $80,000/ year per aircraft ($40 M/year for 500 aircraft). If procedure could be conducted on an air traffic certified Electronic Flight Bag Class 3, the payback for the investment could be less than 3 years. |
| | OI-0353 Reduced Oceanic Separation - Altitude Change Pair-wise Maneuvers<br>NIP: Oceanic In-trail Climb and Descent (TBO) | | | | |
| PRP-007 | **Reduced Non-Radar Separation with ADS-B out (Gulf of Mexico)** | MT Implementation Priority and NowGen | L | H | SBS Program Office estimated $2,320M in capacity and efficiency benefits for high altitude (AT) GOMEX users FY 08-35.<br>SBS Program Office estimated $304M in GA efficiency and capacity benefits to GA and other low altitude users FY 08-35. |
| | OI-0347 Reduced Separation Non-Radar Airspace 5 Miles | | | | |
| | **Negotiated Trajectories** | | | | |
| NT-001 | **Oceanic Airspace; Flexible Entry Timing**<br>**3-013 Oceanic Airspace; Flexible Entry Timing** | Roadmap item | L | M | Fuel savings and additional cargo revenue is approximately $48 million per year |
| | OI-0304 Improved Collaborative Oceanic Routing<br>NIP: Flexible Entry Times for Ocean | | | | |
| NT-002 | **Overhead Flow; Flexible Entry Timing** | Roadmap item | | | Not evaluated |
| NT-003 | **Initial Surface Traffic Management** | MT Implementation Priority | L | H | Total discounted life cycle benefits exceed $250 million dollars with benefit/cost ratios exceeding 6 to 1. Being operated today at Memphis used used by FedEx with significant reductions in taxi-time out. |
| | OI-0320- Surface Management -Level 1<br>NIP: Initial Surface Traffic Management (HD) | | | | |
| NT-004 | **Terminal Airspace; Flexible Entry Timing** | Roadmap item | | | Not evaluated |
| NT-005 | **Route Clearance with RTA** | Priority Research | M | H | The risks are high because of the costs associated with integration of the data communications with the FMS and the FMS upgrades to provide RTA capability is extremely expensive (in the multiple billions of dollars) and the cost to provide the safety assurance level on the ground infrastructure is also likely to be large. Also, the marginal benefits of these capabilities are postulated to be high by JPDO and SESAR but there is little quantitative information to support these claims with the exception of providing a large improvement in controller productivity. |
| NT-006 | **Route Clearance with RTA and Downlink of Expected Trajectory** | Priority Research | H | H | |
| NT-007 | **Trajectory Clearance with RTA and Downlink of Expected Trajectory** | Priority Research | H | H | |
| | OI-0357 Trajectory Based Management – Level 1 Route/Trajectory Digital Exchange | | | | |
| | OI-0358 Trajectory Based Management – Level 2 Trajectory Based Decision Support | | | | |
| | OI-0360 Trajectory-Based Mgmt – Level 3 Automation-Assisted Trajectory Negotiation | | | | |
| | OI-0369 Trajectory Based Management – Level 4 Automated Negotiation/Separation Management | | | | |

| ID | New Short Name | Priority Action | Overall Risk | Overall Benefit | Comments |
|---|---|---|---|---|---|
| NT-009 | **Airborne Lateral/Vertical/Time Clearance** | Roadmap item | H | H | See above |
| NT-010 | **Taxi Lateral / Time Clearance** | Roadmap item | H | H | See above |
| | OI-0357 Trajectory Based Management – Level 1 Route/Trajectory Digital Exchange | | | | |
| | OI-0358 Trajectory Based Management – Level 2 Trajectory Based Decision Support | | | | |
| | OI-0360 Trajectory-Based Mgmt – Level 3 Automation-Assisted Trajectory Negotiation | | | | |
| | OI-0369 Trajectory Based Management – Level 4 Automated Negotiation/Separation Management | | | | |
| | OI-0370 Trajectory Based Management – Level 5 Full Gate-to-Gate | | | | |
| | **Delegated Separation** | | | | |
| DS-001 | **Merging and Spacing** | Priority Research | M | H | Key purposes of the application are to reduce controller workload and to reduce inter-arrival variance, thereby allowing reduced average inter-arrival times and increasing runway throughput. While the reduction in controller instructions / workload for similar applications has widespread documentation, the validity of the specific application in achieving higher throughput is not well documented in literature. Detailed presentation of workload reduction estimates from simulation is provided by the references. Risks are medium because this is being implemented today by UPS in a limited form. |
| | OI-0326 Airborne Merging and Spacing – Single Runway<br>NIP: Delegated Responsibility for Separation (TBO) | | | | |
| | OI-0338, OI-0355, OI-0333 More complex forms of merging and spacing | | | | |
| DS-002 | **Use Optimized Profile Descents (ADS-B/CDTI and ground-based metering)** | NowGen and Priority Research | | | |
| | At SDF with UPS | NowGen | | | Being implemented today by UPS |
| | OI-0329 Airborne Merging and Spacing leading to CDA in higher-density and/or complex airspace | Priority Research | H | H | See discussion associated 2-004b |
| DS-003 | **Delegated Separation for Specific Operations** | Roadmap item | H | M | The benefits associated with these capabilities over and beyond that which occurs with merging and spacing (which is essentially a more complex clearance and not delegation) and enhanced visual approach and IMC CAVS is very uncertain so the benefit was marked as medium. The risks of delegation of responsibility to the pilot is considered high because of issues associated with pilot responsibility and the integrity of the avionics and the separation assurance algorithms. |
| | OI-0356 Delegated Separation – Pair-wise | | | | |
| | OI-0359 Delegated Separation – Oceanic | | | | |
| DS-004 | **Delegated Separation for Complex Operations** | Roadmap item | H | M | |
| | OI-0363 Delegated Separation – Complex | | | | |
| DS-005 | **Delegated Separation in Flow Corridors** | Roadmap item | H | M | |
| | OI-0337 Flow Corridors – Level 1 Static | | | | |
| | OI-0368 Flow Corridors – Level 2 Dynamic | | | | |
| DS-006 | **Paired Approach in IMC to Closely Spaced Parallel Runways (includes depend approaches)** | Priority Research | H | H | The potential benefits of this application are large enough to be a likely incentive to the AC users to consider purchasing the required avionics. About 15 extra arrivals per hour can be achieved over existing procedures (i.e., with single runway operations in IMC, when runway spacing is less than 1200 ft). At the OEP airports, 35 out of 48 runway pairs below 2500 ft spacing are less than 1200 ft apart. Another major benefit of this application is the potential to pave-in-between which means that for some airports a new runway can be built between 2 runways that are now 4300 feet apart. risks are significant because of the performance requirements to operate at these closely -spaced conditions. |
| | OI-0335 Dependent Multiple Approaches in IMC (005) | | | | |

| ID | New Short Name | Priority Action | Overall Risk | Overall Benefit | Comments |
|---|---|---|---|---|---|
| DS-007 | **Independent IMC Approaches to Closely Spaced Parallel Runways** | Priority Research | H | unk | Producing independent closely-spaced parallels is likely to be more demanding than the paired or linked approach concept because there is no spacing to protect against blunders and no wake protection distance calculated. Alsol the marginal benefits of independent over paired operations has not been adequately evaluated. |
| | OI-0334 Independent Parallel or Converging Approaches in IMC<br>NIP: Improved Operations to Closely-Spaced Parallel Runways | | | | |
| DS-008 | **Enhanced Visual Approach** | NowGen | | | Operational approval has been granted to UPS at SDF. |
| | OI-0316 Enhanced Visual Separation for Successive Approaches<br>NIP: Delegated responsbility for Separation | | | | |
| DS-009 | **ADS-B Approach Spacing** | Priority Research | H | H | These results show an increase between 2 and 15 operations per runway per hour depending on the final separations that the pilots are comfortable maintaining using IMC CAVS. Benefits results range from $38 million per year to $600 million per year depending on the amount of equipage and what is factored into the analysis. |
| DS-010 | **Deconflicted Missed Approaches for Converging** | Roadmap item | | | Not addressed |
| **Low-Visibility/Ceiling Approach /Departure/Taxi** | | | | | |
| LV-001 | **Low Visibility/Ceiling Approach Operations** | NowGen (EVS)/ Priority research (GBAS) | M | M | This analysis indicates that the major benefits of LAAS in the US is not in achieving CAT I but in CAT III. However, the uncertainty in the cost of a CAT III via LAAS or other methods (e.g., EVS) means that the costs may not cover the benefits. FAA's commitment is to developing standards and supporting research and the burden for avionics development is borne by industry. This is labelled a high priority research area because representatives from industry believe that not all the important benefits have been assessed adequately. |
| | OI-381 Near-all Weather Airport Access<br>NIP: Ground-based augmentation System (GBAS) | | | | |
| LV-002 | **Low Visibility/Ceiling Landing Operations** | Roadmap item | H | L | The benefits associated with all weather airport access operations is considered low because zero-zero weather happens so infrequently. The benefits associated with all weather conditions as compared to near-all weather conditions are low because it happens so rarely in the US. However, worldwide, the benefits could be larger. |
| | OI-0317 All Weather Airport Access | | | | |
| LV-003 | **Low Visibility/Ceiling Takeoff Operations** | Roadmap item | | | Not evaluated |
| | OI-381 Near-all Weather Airport Access | | | | |
| LV-004 | **Low Visibility Surface Operations** | Roadmap item | H | L | See above (5-002) |
| | OI-0322 Low Visibility Surface Operations | | | | |
| **ATM Efficiencies** | | | | | |
| ATM-001 | **Data Link Departure Taxi Clearance and Pre-departure Clearance** | | H** | H | **Adding new capabilities to the data link standards is a high risk for the mid-term and the marginal benefits of providing this information over what is provided today is not clear. However, there is some indication that the benefits could be high by providing taxi clearance displays to the cockpit which will improve runway safety concerns. Also, there is evidence that the time to trasmit taxi clearance changes by voice results in surface movement inefficiencies, Risks are considerably less if the standards are targetted for the longer-term. |
| | OI-0321 Surface Management – Level 2 Datalink/Departures<br>NIP: Enhanced Surface Traffic Operations | | | | |

| ID | New Short Name | Priority Action | Overall Risk | Overall Benefit | Comments |
|---|---|---|---|---|---|
| ATM-002 | **Data Link En Route Clearance Delivery and Frequency Changes** | MT Implementation Priority | L** | H | ** Note: The risks are high for the policies that incentivize avionics equipage so if this is not addressed the risk is high. Technically this operation has been tested in Miami and is being deployed in Europe. Benefits are improved Controller Productivity (up to 14%). Annual savings to FAA is estimated to be just under $100 million per year and to users by 2022 $220 million per year; Several analyses indicate that approximately 20% of all en route operational errors (OEs) are communications related . With data communications, most of these OEs could be eliminated. |
| | OI-0352 Automated Clearance Delivery and Frequency Changes | | | | |
| ATM-003 | **Data Link Arrival Taxi Instructions** | Roadmap Item | | | Not evaluated |
| | OI-0327 Surface Management – Level 3 Arrivals/Winter Operations/Runway | | | | |
| ATM-004 | **Data Link NAS Information and Advisories** | Roadmap item | | | Not evaluated |
| ATM-005 | **Increase Access and Throughput at Non-Non-Towered/Uncontrolled Airports** | Roadmap item | H | H | Extending this to the surface and providing "separation functions provided either by ground automation or through aircraft-based conflict detection/resolution algorithms" is a mjaor technical challenge requiring signficant R and D and development (for automated virtual towers). The benefits are high because virtual towers could provide significantly more services to the smaller airports in a metroplex area and that would relieve traffic at some of the major airports. This could be done without providing costly infrastructure. |
| | OI-0313 Virtual Towers – Level 1 Sequencing, Separation, and Spacing | | | | |
| | OI-0315 Virtual Towers – Level 2 Sequencing, Separation, Spacing, and Surface Management | | | | |
| ATM-006 | **Reduce Weather Impacts through Improved Forecasting** | Roadmap item | H | H | Weather delays are more than an inconvenience; they cost the nation's airlines, cargo carriers, and other users in excess of $4 billion annually. According to FAA research, 29 peak delay days could wipe out an airline's profits for the entire year. FAA projections show a doubling to tripling of flight operations by 2025 which would further magnify the impact of bad weather on the air transportation system. If major changes are not made by 2025, there could be 87 days with delays worse than the worst day in 2004, a year when U.S. air travel was often severely impacted by weather. Based on today's estimates, perhaps as much as sixty-percent of such impacts are potentially avoidable weather situations (Sherry, 2007). This was from an avionics perspective not included as a major item because the case has not been made that improved weather sensors on the aircraft will play a major role in improving weather forecasts and thus addressing the problems mentioned above. |
| | OI-2020 – Weather Information Supports NextGen Implementation Goals – Level 1 | | | | |
| | OI-2021 - Weather Information Supports NextGen Implementation Goals – Level 2 | | | | |
| | OI-2022 - Weather Information Supports NextGen Implementation goals – Level 3 | | | | |

**Table 4-2. Detailed Evaluation of Mid-Term Implementation Priorities**

| Evaluation Criteria | Integrated Arrival / Departure Management (PRP-002) | 2D RNP with Curved Segments (PRP-001) | Initial Surface Traffic Management (NT-003) | Data Link En Route Clearance Delivery and Frequency Changes (ATM-002) | Surface Collision Avoidance (Aircraft-based) (SAFE-005) | On Demand NAS Information (SAFE-002) (SAFE-006) | Reduced Oceanic and Non-Radar Separation (PRP-007) |
|---|---|---|---|---|---|---|---|
| Problem solved. | Throughput | Capacity | Efficiency | Capacity | Safety | Safety | Efficiency |
| Benefits (how realized, quantified and confidence level). | Table 4-4 | Table 4-4 | Table 4-8 | Table 4-5 | Table 4-6 | Table 4-3 | Table 4-3 |
| What avionics, ground systems and/or procedures are required to support it? | Table 2-4<br>RNAV | Table 2-4<br>RNP SAAAR<br>RNP<br>RF Leg Capability | Table 2-2<br>ADS-B | Table 2-2<br>FANS 1/A+<br>FANS 2/B<br>ATN Baseline 1 | Table 2-2<br>ADS-B<br><br>Table 2-5<br>CDTI<br>Moving Map | Table 2-2<br>FANS 1/A+<br>FANS 2/B<br>ATN Baseline 1<br><br>Table 2-5<br>Moving Map<br><br>Table 1-6<br>FIS-B | Table 2-3<br>ADS-B Out |
| Are those avionics, ground systems and/or procedures consistent with end-state designs and applications? | Yes | Yes | Yes | Yes, consistent, but there will be an evolution | Yes, but may evolve to Class 3 EFB or embedded CDTI | Yes | Yes |
| Ops Concept done | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Avionics standards | AC 90-100A, TSO-C115, TSO-C129, TSO-C145, TSO-C146, TSO-C166, Order 8260.44, Order 7100.9 | AC90-RNP | ADS-B reg, AC 20-ADSB, TSO-C154b, TSO-C166a | ICAO PANS-ATM, ICAO 9880, AC20-140, AC120-70B, DO290/2, DO-280B, ARINC 631 | DO-260 + TBD for C-2 Electronic Flight Bag, combination not yet certified or approved | AC 20-149, AC 00-63C | Euro Aviation Safety Agency acceptable means of compliance 20-24 |
| Ground systems requirements defined | TBD | Yes | Yes (as implemented at FedEx) | DO290/2 & DO-280B | Yes | Yes | Yes |
| Procedures defined | TBD | In process | Yes | Yes | Yes | Yes | Yes |
| Equipage Initial Operational Capability? | TBD | Exists today | Latest NGIP has this mid-term | European mandate 2011 | Exists today | Exists today | Exists today |

| Evaluation Criteria | Integrated Arrival / Departure Management (PRP-002) | 2D RNP with Curved Segments (PRP-001) | Initial Surface Traffic Management (NT-003) | Data Link En Route Clearance Delivery and Frequency Changes (ATM-002) | Surface Collision Avoidance (Aircraft-based) (SAFE-005) | On Demand NAS Information (SAFE-002) (SAFE-006) | Reduced Oceanic and Non-Radar Separation (PRP-007) |
|---|---|---|---|---|---|---|---|
| Ground system Initial Operational Capability? | Latest NGIP has this mid-term | Exists | Latest NGIP has this mid-term | ~2014 | Exists | 2011 | 2011 |
| What other operational capabilities do these avionics, ground systems and/or procedures support? | TBD | TBD | TBD | TBD | TBD | TBD | TBD |

A more detailed presentation of the benefits of each of the mid-term implementation priorities is presented in Tables 4-3 through 4-8.

**Table 4-3. ADS-B Out Benefits Substantiation**

| Avionics | Capability | User Class | Airspace User | FAA | Society |
|---|---|---|---|---|---|
| ADS-B Out (1090ES or UAT)<br><br>GPS position source | PRP-007 Reduced Non-Radar Separation (ADS-B Out for Non-Radar Separation) | AT and high-end GA | SBS Program Office estimated $2,320M in capacity and efficiency benefits for high altitude (AT) GOMEX users FY 08-35 [1]<br>SBS Program Office estimated $304M in GA efficiency and capacity benefits to GA and other low altitude users FY 08-35 [2] | SBS Program Office estimates savings in radar replacement and installation of new radars of 1.26 billion dollars between 08-35 [3] | Provides increased safety resulting from increased provision of IFR services in areas that currently do not have radar and for improved search and rescue resulting in areas without radar services. [4] |
| | OEP: On Demand NAS Information, SAFE-002 Weather Avoidance, SAFE-006 Airspace Avoidance, Traffic Display (FIS-B and Display of Traffic) | Mostly GA | | | Reduced GA weather related accidents due to improved weather situational awareness<br>Reduced GA mid-air collisions and near-miss incidents due to improved traffic situational awareness<br>SBS Program Office estimates FIS-B and ADS-B based traffic situational awareness will yield $1,673M (FIS-B) and $720M (Traffic) in user benefit between FY08-35 [5] |

| Avionics | Capability | User Class | Airspace User | FAA | Society |
|---|---|---|---|---|---|
| ADS-B Out (1090ES or UAT)<br><br>GPS position source | Improved Surface Traffic Management | All | With ADS-B Out, the tower as well as the RAMP personnel can see the aircraft and better manage surface operations thus reducing taxi times.<br>Also, there are times when ASDE-X is not effective (during heavy precipitation), and ADS-B is effective. The SBS office projects a FY08-35 benefit of around $100 million. [6] However, this is not complete because it doesn't address other airports and benefits to the users by having the RAMP area surveilled. Surveillance and Broadcast Services Benefits Basis of Estimate; Table 2-14; August 2007 | | |

**Table 4-4 – RNP and RNAV Benefits Substantiation**

| Avionics | Capability | User Class | Airspace User | FAA | Society |
|---|---|---|---|---|---|
| RNP-1 and 0.3 navigation capability with RF Legs | 2D RNP with Curved Segments – PRP-001<br>Reduce Lateral Track Spacing using RNP (RNP Approach/Departure/Arrival with RF Legs) | AT and high-end GA | De-conflicting arrivals and departures for adjacent airports<br>Improved access to under-utilized runways<br>Improves access to airports during IFR conditions where there are obstacles to straight in approaches<br>CAASD estimate of benefits are in the 10's of millions per year [7] | Reduced controller workload from reducing vectoring and communications | Enhanced safety through guidance to the runway and terrain avoidance<br>Fuel and emissions benefits from improved descent continuity and shorter paths<br><br>Reduced incidents of runway "excursions"<br><br>Better access to secondary airports and improved ability to transit high density airspace. |

| Avionics | Capability | User Class | Airspace User | FAA | Society |
|---|---|---|---|---|---|
| RNAV required for specific airports | PRP-002 Integrated Arrival/Departure Management (RNAV) | AT and high-end GA | Enables more routes in congested airspace to meet demand and allow flexibility. Underutilized airspace can be used quickly and effectively to keep the system moving when other areas become busy or impacted by adverse weather. ($4.5B through 2024 over 9 locations) [8] | Reduced controller workload from reducing vectoring and communications | Fuel and emissions benefits from reduced delays and less vectoring |

**Table 4-5 – Data Link Segment 1 Benefits Substantiation**

| Avionics | Capability | User Class | Airspace User | FAA | Society |
|---|---|---|---|---|---|
| VDL-2 Transceiver, CMU, and display integration<br>FANS 1/A or ATN Baseline 1 Applications<br>FMS integration desired but not required | ATM-002 Data Link En Route Clearance Delivery and Frequency Changes | | Improved Operational Efficiency in Convective Weather [9]<br>Reduced Fuel Usage and Related Costs through reduction in delay [9]<br>Annual savings to airlines in 2022 is estimated to be over $200 million per year [9] | Improved Controller Productivity (up to 14%) [10]<br>Annual savings to the FAA is estimated to be just under $100 million per year [9] | Several analyses indicate that approximately 20% of all en route operational errors (OEs) are communications related. With data communications, most of these OEs could be eliminated [9] |

**Table 4-6 – Surface Moving Map and /or Runway Awareness and Advisory System (RAAS) Benefits Substantiation**

| Avionics | Capability | User Class | Airspace User | FAA | Society |
|---|---|---|---|---|---|
| Class 2 EFB or MFD/PFD<br>GPS position source (probably SBAS enhanced<br>ADS-B In (1090ES or UAT) and/or RAAS avionics | SAFE-005 Surface Collision Avoidance: Aircraft-based | All | There is some indication that moving maps provide the pilot with better information about taxiway exits and thus speeds up their exit time on the runway. Not clear that will apply to Class 2 devices. | | Reduction in runway incursions: between 28% and 95%. [11].<br>RAAS provides 46% mitigation for wrong runway departures but data not found on overall runway incursions [11]. |

| Table 4-7 – ADS-B In Benefits Substantiation | | | | | |
|---|---|---|---|---|---|
| **Avionics** | **Capability** | **User Class** | **Airspace User** | **FAA** | **Society** |
| Leader Aircraft:<br>ADS-B Out (Assumed 1090ES)<br>GPS possibly SBAS position source<br>Follower Aircraft:<br>ADS-B In (Assumed 1090 ES)<br>GPS possibly SBAS position source<br>CDTI with CSPA application<br>ILS, LPV or GLS | DS-006 Paired Approach in IMC to Closely-Spaced Parallel Runways | AT and high-end GA | Higher capacity and throughput to closely-spaced parallel runways even during low visibility (initial implementation may be high ceilings)<br>There are 48 runway pairs in the NAS currently spaced between 700 and 2500 feet. that could in principle use the procedure<br>New runways 700 feet from existing runways on largely existing airport property could probably be built at 18 landlocked airports that could also use the procedure [12]<br>Benefits are significant (TBD) | | Reduced delays results in reduced fuel use and emissions |
| Leader Aircraft<br>ADS-B Out<br>GPS position source<br>Follower Aircraft<br>ADS-B In<br>CDTI with CAVS Application<br>GPS position source | CAVS in MMC conditions – DS-008 Enhanced Visual Approach | AT and high-end GA | Increased opportunities to land at near VMC capacities during MMC<br>For advanced versions of procedure, operations may increase arrival rates to parallel or converging runways<br>Benefits for initial Marginal VMC CAVS of $600M/ year [13] | Operating in visual conditions is generally less workload for the controllers | Reduced delays results in reduced fuel use and emissions |

| Table 4-8 – Surface Traffic Management System Benefits Substantiation | | | | | |
|---|---|---|---|---|---|
| **Avionics** | **Capability** | **User Class** | **Airspace User** | **FAA** | **Society** |
| Mode- C or Mode-S and/or ADS-B Out | NT-003 Initial Surface Traffic Management (ATM and Ramp) | All | Average taxi-out time for FedEx aircraft is 1.3 minutes less with surveillance during VA conditions and 4.3 minutes less with surveillance during IA conditions using surveillance outage data when MEM in North Flow operation. Also, the percentage of taxi-out times that are greater than 40 minutes decreases by at least half. No significant change in taxi-out during South Flow. [14]<br>Total discounted life cycle benefits exceed $250 million with benefit/cost ratios exceeding 6 to 1. [15] | | Reduced emission from less taxi times and better gate management |

## Key Enabler Benefits Substantiation References


1-6. Surveillance and Broadcast Services Benefits Basis of Estimate, August 2007.

7. MITRE/CAASD estimated based on information presented in the Performance-based operations Aviation Rulemaking Committee report entitled "Applications and Priorities for RNP Instrument Approach Procedure Implementation Report", February 2005.

8. Federal Aviation Administration (FAA), Air Traffic Organization Operations (ATO) Planning "Integrated Arrival/Departure Control Service (Big Airspace) Concept Validation", September 2007.

9. FAA, ATO-W, "Benefits Basis of Estimate, Data Communications Program, Initial Investment Analysis" v0.04, July 2008.

10. MITRE/CAASD, "Data Link Benefit-Cost Analysis Methodology", MTR04W0000081R1, September 2005.

11. From Aviation Week and Space Technology, April 7, 2008 (p.47). "About 55% of Class A and B types of mishaps are caused by pilot deviation—that is, the aircraft is maneuvered to the wrong location. The improved situational awareness of an airport moving map with the aircraft's position marked could eliminate half of these types of mishaps, according to the CAST findings. The other 45% of mishaps could be addressed only when it is possible to show pilots where other surface traffic is located." CAST determined that 95 percent of all runway incursions could be prevented by having (1) a cockpit moving map display with own-ship position for improved situational awareness, (2) integration of ADS-B to enable pilots and controllers to see all aircraft and vehicles on the surface and aircraft up to 1,000 feet above ground level, (3) automatic runway occupancy alerting, and, (4) digital data-linked clearances that are then displayed on the moving map (ALPA, White Paper: Runway Incursions: A Call to Action, March 2007). Thus ownership with proximate traffic would lie between the 28% value and the 95% value. Glenn Michaels in his briefing entitled "FAA Call to Action on Runway Safety Short-term Actions" presents the JIMDAT Mitigation Assessment as about 46% reduction utilization of the wrong runway. However, the assessment of RAAS is similar for using the wrong departure runway.

12. Mundra, Anand, "ADS-B/CDTI Applications Under Investigation in an Internal MITRE Research Program", March 9, 2008.

13. A study by MCR Federal, Inc (Safe Flight 21 CDTI Enhanced Flight Rules (CEFR) Initial Benefit Analysis (Version 3, May 2003)) evaluated the potential benefits of this application. The results show a $315M annual savings at the top 31 busiest airports. This is a conservative estimate because the MCR study assessed benefits according to the actual airports' VMC rules that fall heterogeneously between two scenarios: Level Two CFR (visibility >= 5 mi and ceiling >= 3000 ft) and Level Three CFR (visibility >= 3 mi and ceiling >= 1000 ft). Cirillo notes that the delay savings benefit of the Level Three CFR scenario is double that of Level Two CFR scenario (Cirillo, M., 2002, AW-2: Space Closer to Visual Standards / CDTI-Enhanced Flight Rules –Decision Status, Washington DC: Federal Aviation Administration).

14. Howell, Dan, Effect of Surface Surveillance Data Sharing on FedEx Operations at Memphis International Airport, <u>ATC Quarterly</u>, Modified 4 July 2007.

15. Atkins, Stephen et al, <u>Surface Management System Field Trial Results</u>, <u>AIAA</u> 4th Aviation Technology, Integration and Operations (ATIO) Forum, 20 - 22 September 2004, Chicago, Illinois.


## Appendix 5 – General Aviation Supporting Information

Airspace access in the NextGen will be performance driven. Operators will have to make equipment decisions based on their mission objectives, cost to equip, benefits, and other supporting aircraft system capabilities. Different segments of the aviation community will desire different levels of access to airspace based on aircraft performance, desired operational capacity, and safety enhancements. In general terms, the scheduled air transport operators will desire greater efficiency and predictability of operations and will be able to justify higher levels of equipage. GA represents a much broader level of users and capabilities and will therefore have a wider range of operational needs going from basic point-to-point operations in visual conditions outside of high density airspace, to operations into and through high density airspace to both satellite and primary airports in large metroplexes. The purpose of this appendix is to characterize the wide range of desired capabilities of GA.

Aircraft will have a spectrum of options to meet these requirements. If a pilot-aircraft combination can meet an RTA tolerance with manual flight, then they can participate without automating equipage. Other pilot-aircraft combinations may need decision aids to assist the pilot in meeting the same RTA tolerance, while still others may opt for automation such as FMS-type coupling between navigation and aircraft control.

Scheduled Air Transport operators and GA operators may meet the same performance requirements in given airspace in different ways. Table GA-1 shows key contrasts between these two operator communities. The avionics architectures vary considerably between air transport and GA in 2010 and will probably continue to vary. Air transport will probably continue along a highly-integrated FMS-centric path while most of GA—especially piston—follows a modular "panel-mounted" path more easily tailored to GA's very diverse missions and business cases. GA and air transport also may differ in the choice of systems, as well as architecture. For example, GA has already embraced WAAS and LPV approaches, which provide high benefits at relatively low cost for most GA airports and operators, while the air transport community is moving toward LAAS/GBAS technology for precision approaches. NextGen policy must allow multiple paths to evolve into NextGen performance solutions.

The near-term NextGen GA equipage is the conversion to GNSS/SBS RNAV. This conversion has been underway since the 1990s. The introduction of LPV approaches has increased IFR access significantly and motivates tens of thousands of aircraft owners to equip with IFR GPS-WAAS units. Low cost ADS-B In augmentation of ADS-B Out—with benefits—will motivate owners to equip with ADS-B In as well as ADS-B Out.

**Table GA-1: Comparison of General Aviation and Air Transport in 2010 Assume VFR operations are unchanged**

| Characteristic | General Aviation | Scheduled Air Transport |
|---|---|---|
| **Schedule** | On-Demand | On-Schedule |
| **Mission Type** | Passenger and cargo plus training, recreation, aerial services, etc. | Passenger and cargo |
| **Destinations** | Destinations vary widely (over 5,000 public-use U.S. airports) and include off-airport operations. Small percentage of OEP operations. | Specific destinations with a minimum level of infrastructure and security (about 400 U.S. airports). Large percentage of OEP operations. |
| **Altitudes** | Large percentage of missions are completely below 18,000 feet | Few missions are completely below 18,000 feet, although all have some portion (takeoff and landing) below 18,000 feet. |
| **Aircraft Type** | Diverse family of aircraft, including no engine, piston, turbo-prop, jet, and single and multi-engine | Predominately jet and multi-engine |
| **Fleet Size** | Small and single-aircraft "fleets" | Large Fleets |
| **Crew Size** | Frequently Single-Pilot | Multi-Pilot Crew |
| **Type of Operations** | High percentage of VFR missions (under 18000 feet) | Always IFR |

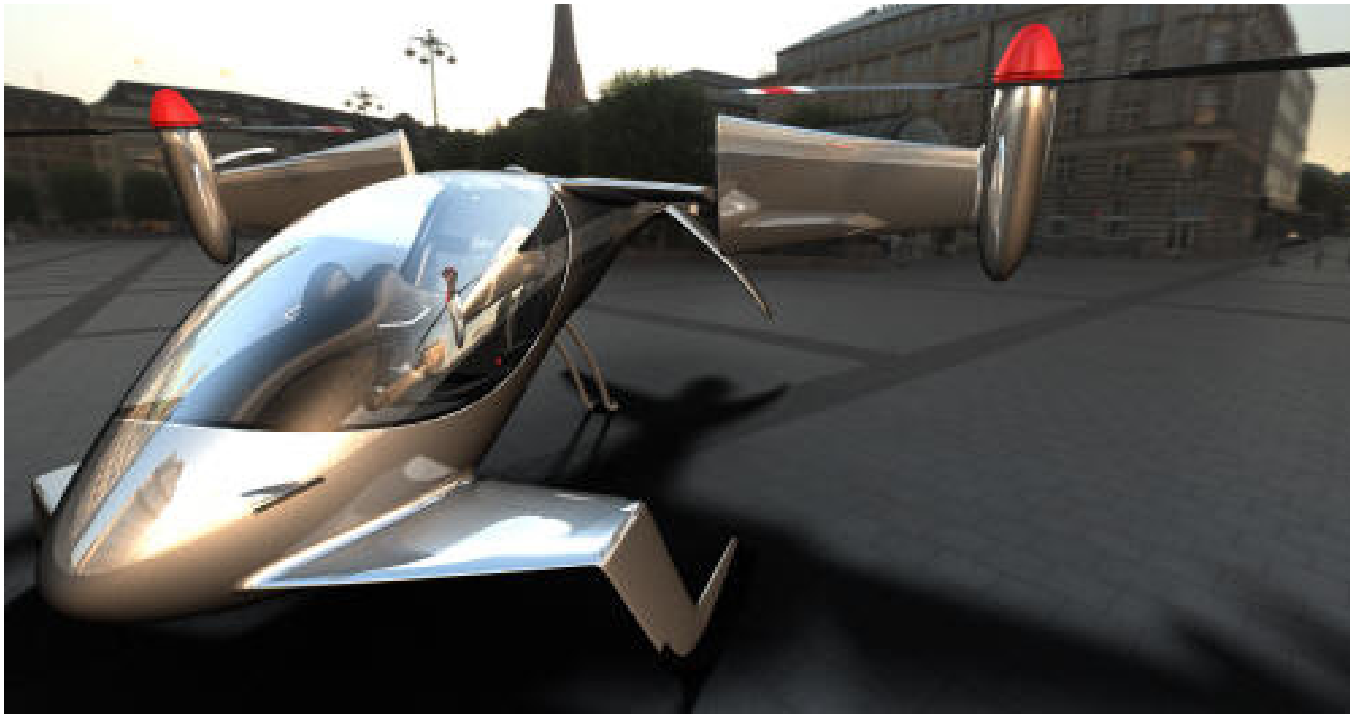
| Characteristic | General Aviation | Scheduled Air Transport |
|---|---|---|
| **Operations Support** | No Flight Operations Center/Dispatcher support; relies on Flight Service Stations | Extensive FOC/Dispatcher Support |
| **Training** | Starts pilots from zero time; mostly done in low-performance piston aircraft in small schools; often informal | Builds on general aviation or military training; Extensive use of sophisticated simulators and formal curricula |
| **Flight Plan** | Large percentage of operations performed without a formal flight plan | All operations performed on a formal flight plan |
| **ANSP Workload** | Majority of VFR operations have low or no ANSP involvement | All operations have ANSP involvement |

Within the general aviation community, flights can originate or end at unusual locations and for unusual purposes. Flights are for business, safety, and leisure. The NextGen airspace design and equipage requirements must consider these operations. General aviation aircraft are best defined by Table GA-2, and different segments come with varying physical, piloting, and economic capabilities. Examples of different types of operations are:

- Flights to or from smaller airports to other smaller airports or metroplex airports, or through metroplex airspace
- Air ambulance, fire fighting, and police patrol
- Helicopter transport or cargo operations
- Crop dusting
- Gliders, airship and hot air balloons for entertainment or surveillance
- Sight seeing and tourist transport
- IFR and VFR training

| Table GA-2: General Aviation Segments |
|---|
| General Aviation: All manned aviation activity other than scheduled air transport and military. Fixed-wing and rotary-wing, this includes personal, business, charter, training, on-demand cargo, air ambulance, charity, etc. |
| High-end Jet GA: Corporate and fractional operations using Business Jets at medium to high altitudes across all aspects of the national airspace, 25-45,000 ft. Flights are point to point and may/may not include OEP 35 class airports. These aircraft are well equipped with sophisticated flight management systems, are RNP capable, TCAS, and may have some enhanced or synthetic vision system. |
| High-performance fixed-wing piston GA: Owner- and corporate-operated aircraft including turboprops and turbo-charged pistons operating up through FL240. These aircraft may have limited flight management systems, glass cockpits, auto-flight systems, vision systems, and may use enhanced services such as XM weather and traffic services. |
| Low-Altitude Fixed-Wing Piston GA: A wide range of aircraft types from small turboprops, twin pistons, and SE pistons. These aircraft are used for VFR and IFR flight. Some are used primarily for recreation and some for business, or a combination. These aircraft have a wide range of capability and operate below 18,000 ft, with the majority below 12,500 feet. Destinations may include OEP airports serving GA as well as air transport, such as HOU, CLT, CLE, etc. |
| Technically-Advanced Piston GA Aircraft (TAA-piston): A specialized fleet with considerable sophistication to include ADS-B and RNP capability, auto-flight systems, vision systems, and glass cockpits. Those with normally-aspirated engines operate below 12,500 ft. |

| |
|---|
| Helicopter: Rotary-wing aircraft typically performing short-range missions including emergency medical service, tourist, oil rig support, and traffic/news coverage. The majority of Helicopters operate in both VFR and some IFR capability, normally within 5,000 ft. of the surface. Many operate in high density congested population centers. |
| Airship: Lighter than air (LTA), these are used for touring, advertising, aerial photography, and other unique missions. Majority of operations are VFR, usually in populated areas, but frequently IFR between events. Normally operate within 5,000 ft. of surface. |
| Light-Sport Aircraft (LSA): Many light-sport aircraft designs exist; they have limited gross weight (less than 1320 pounds or 600 kg), capability, speed, and range. Limited to pilot and one passenger. Light sport aircraft (LSA) are entirely daytime VFR recreational by regulation. |
| Experimental: Many unique designs and a wide range of performance; some exceed the performance and range of production aircraft in the same weight and horsepower range. Many are amateur-built. Regulations prohibit use of experimental aircraft for revenue-producing flights, but some aircraft in the experimental exhibition class are operated by organizations and participate in public events such as air shows. The majority are operated VFR, but some have IFR capability. Most operate normally below 12,500 ft; however, some experimental aircraft are jets and operate at high altitude—for example, historic jets operated under experimental exhibition classification. |
| Gliders: Also called sailplanes, usually devoted to unpowered VFR recreational flying. A few have engines used during take-off, but the great majority has no altitude control, although they have full directional control. Most activity is below 18,000 feet; however, in certain areas, wave soaring takes these aircraft up to flight levels. Some reach FL450. Few gliders have electrical systems, but increasingly they are equipped with transponders and radios powered by battery. |
| Ultralight Vehicles: Mostly single-seat aircraft carrying less than 5 U.S. gallons (19 Liters) of fuel, empty weight of less than 254 pounds (115 kg), top speed of 55 knots, and maximum stall speed under 24 knots. Ultralights include gliders under 155 pounds empty weight, gyroplanes, powered parachutes, and weight-shift control vehicles. They may be flown only in daytime VFR in uncontrolled airspace over unpopulated areas. Some two-seat training versions exist. Pilot licenses are not required for ultralight operation; consequently, they are officially called "vehicles" and not aircraft (governed by FAR 103). |
| Hot Air Balloons: Also in the lighter-than-air (LTA) category, hot-air balloons have some altitude control but no directional control. They are usually devoted to unpowered VFR recreational flying and sightseeing at low altitudes. |



## Appendix 6: Key Policy Issues Associated with the Roadmap Operational Capabilities

The following table identifies NextGen policy issues (as noted in the IWP) that impact near- and mid-term aircraft capabilities. Policy issues that will impact long-term capabilities will be identified in future versions of the Avionics Roadmap.

**Table 5-1 – Key Policy Issues and Roadmap Operational Capability Impacts**

| IWP Policy | Description | Affected Capabilities |
|---|---|---|
| PI-0004 | ATM Automation Development, Performance and Interoperability Standards | SAFE-007: Wake Avoidance and Mitigation – Air/Ground Combination<br>NT-005: Route Clearance with RTA<br>NT-006: Route Clearance with RTA and Downlink of Expected Trajectory<br>NT-008: Airborne Lateral/Vertical/Time Clearance<br>NT-009: Taxi Lateral/Time Clearance<br>ATM-001: Data Link Pre-departure Clearance Revisions<br>ATM-002: Data Link En Route Clearance Delivery and Frequency Changes<br>ATM-003: Data Link Taxi Instructions |
| PI-0007 | Rules of the Road (Priority access to equipped aircraft) | All closely-spaced parallel approach and delegated separation (DS) capabilities<br>All data link (NT) dependent applications |
| PI-0010 | National Surveillance Strategy (including backup surveillance and ADS-B position strategies) | SAFE-004: Airborne Collision Avoidance<br>SAFE-005: Surface Collision Avoidance<br>DS-003: Delegated Separation for Specific Operations<br>DS-004: Delegated Separation for Complex Operations<br>DS-005: Delegated Separation in Flow Corridors<br>DS-006: Paired Approach in IMC to Closely-Spaced Parallel Runways<br>DS-007: Independent IMC Approaches to Closely-Spaced Parallel Runways<br>DS-008: Enhanced Visual Approach<br>DS-009: ADS-B Approach Spacing<br>DS-007: Independent IMC Approaches to Closely-Spaced Parallel Runways<br>DS-008: Enhanced Visual Approach<br>SAFE-005: Surface Collision Avoidance<br>DS-003: Delegated Separation for Specific Operations<br>DS-004: Delegated Separation for Complex Operations<br>DS-005: Delegated Separation in Flow Corridors<br>DS-006: Paired Approach in IMC to Closely-Spaced Parallel Runways<br>DS-007: Independent IMC Approaches to Closely-Spaced Parallel Runways<br>DS-008: Enhanced Visual Approach<br>DS-009: ADS-B Approach Spacing<br>LV-002: Low Visibility/Ceiling Landing Operations |

| IWP Policy | Description | Affected Capabilities |
|---|---|---|
| PI-0014 | Aircraft Equipage Implementation Policy (including operational incentives, economic incentives (e.g., tax credits) and/or mandates. Objective criteria should define when voluntary incentives are abandoned in favor of mandates. | All |
| PI-0017 | Communications Architecture Plan for Ground, Space, Airborne, and/or Performance-Based Architectures – (Decision on data communications performance requirements and the utilization of specific system and/or performance based systems) | NT-005: Route Clearance with RTA<br>NT-006: Route Clearance with RTA and Downlink of Expected Trajectory<br>NT-008: Airborne Lateral/Vertical/Time Clearance<br>NT-009: Taxi Lateral/Time Clearance<br>ATM-001: Data Link Pre-departure Clearance Revisions<br>ATM-002: Data Link En Route Clearance Delivery and Frequency Changes<br>ATM-003: Data Link Taxi Instructions<br>ATM-004: Data Link NAS Information and Advisories<br>ATM-005: Increase Access and Throughput at Non-Towered/Uncontrolled Airports<br>ATM-006: Reduce Weather Impacts through Improved Forecasting |
| PI-0088 | Federal vs. Private Role In Weather Services (including fee vs. no-fee government services) | SAFE-002: Weather Avoidance |
| PI-0101 | Initial Aviation Environmental Policy (environmental standards and streamline environmental review processes) | PRP-002: Integrated Arrival/Departure Airspace Management |
| PI-0115 | NextGen Safety Assessment/Certification - Synchronized and/or Integrated Aircraft and ANS Capabilities and Certification Standards | SAFE-007: Wake Avoidance and Mitigation – Air/Ground Combination<br>SAFE-008: Wake Avoidance and Mitigation – Aircraft-Based<br>PRP-006: Reduced Oceanic Separation – Altitude Change Pair-wise Maneuvers<br>DS-003: Delegated Separation for Specific Operations<br>DS-004: Delegated Separation for Complex Operations<br>DS-005: Delegated Separation in Flow Corridors<br>DS-006: Paired Approach in IMC to Closely-Spaced Parallel Runways<br>DS-007: Independent IMC Approaches to Closely-Spaced Parallel Runways<br>DS-008: Enhanced Visual Approach<br>DS-009: ADS-B Approach Spacing |

## Appendix 6: Aircraft Working Group Participants and Support Staff

The Aircraft Working Group members that participated in at least one scheduled meeting of the working group (October 2007 – October 2008) are listed in Tables 6-1 and 6-2

**Table 6-1 – Participants of the Aircraft Working Group**

| Name | Agency/Company |
|---|---|
| Kathy Abbott | FAA |
| Rose Ashford | NASA |
| Frank Alexander | IATA |
| Chad Balentine | ALPA |
| Clay Barber | Garmin |
| Chris Benich | Honeywell |
| Jake Biggs | Cessna |
| Randy Bregger | Bell Helicopter |
| Hank Cabler | FAA |
| Mike Cramer | MITRE |
| James Davis | Free Flight Systems |
| Bruce DeCleene | FAA |
| Colleen Donovan | FAA |
| Jim Duke | SAIC |
| Charles Durkin | Day Jet Corp. |
| Jeff Duven | FAA |
| Kristin Farry | Excalibur/AOPA |
| Scott Foose | RAA |
| Mark Fox | FAA |
| Eldridge Frazier | FAA |
| Steven Hampton | ERAU |
| Richard Heinrich | Rockwell Collins, Inc |
| Doug Helton | Aviation Management Associates |
| Stephen Jacklin | NASA |
| Pascal Joly | Airbus Americas |
| Dwayne Kimball | Hawker Beechcraft |
| Worth Kirkman | MITRE |
| Marti Klemm | ERAU |
| Xiaogong Lee | FAA |

| Name | Agency/Company |
|---|---|
| Frank Mangine | FAA |
| David Manville | U.S. Army |
| George Marania | FAA |
| Hugues Meunier | Thales |
| Goran Mrkoci | BAE Systems |
| Dave Nakamura | Boeing |
| Rob Pappas | FAA |
| Dharmesh Patel | Honeywell |
| Art Politano | FAA |
| Trent Prange | FAA |
| Jean-Claude Richard | Thales Avionics |
| Brian E. Smith | NASA |
| Scott Stevens | FAA |
| John Schwoyer | FAA |
| Ronald Stroup | Airline Dispatchers Federation |
| Don Taylor | FAA |
| Scott Taylor | Air Force |
| Stephen Van Trees | FAA |
| Jeffrey Viken | NASA |
| Keith Wichman | GE Aviation |

**Table 6-2 – Support Staff of the Aircraft Working Group**

| Name | Agency/Company |
|---|---|
| Selam Firdaweke | HMMH |
| John Bioty | Booz Allen |
| Eric Lautenschlager | ANSER |
| Sean McCourt | MITRE |
| Skip Monk | FAA |
| Joseph Palermo | Booz Allen |
| Art Smith | MITRE |
| Sean Stapleton | MITRE |
| Todd Stock | MITRE |
| Rick Towle | Sensis |
| Ryan Kelchner | Booz Allen |

## Appendix 7: Glossary

| | |
|---|---|
| 4D ASAS | 4D Airborne Separation Assurance Systems |
| AC | Advisory Circular |
| ACAMS | Aircraft Condition Analysis and Management System |
| ACARS | Aircraft Communications Addressing and Reporting System |
| ADS-B | Automatic Dependent Surveillance-Broadcast |
| ADS-C | Automatic Dependent Surveillance-Contract |
| AIAA | American Institute of Aeronautics and Astronautics, Inc. |
| ALPA | Airline Pilots Association |
| ANP | Air Navigation Plan |
| ANS | Air Navigation System |
| ANSP | Air Navigation Service Provider |
| AOA | Aircraft Operation Area |
| AOA | ATN Over ACARS |
| AOC | Airline Operational Control |
| AOPA | Aircraft Owners and Pilots Association |
| ARINC | Aeronautical Radio Incorporated |
| ARM | Avionics Roadmap |
| ASDE-X | Airport Surface Detection Equipment, Model X |
| AT | Air Traffic |
| ATC | Air Traffic Control |
| ATIO | Aviation Technology, Integration and Operations |
| ATM | Air Traffic Management |
| ATN | Aeronautical Telecommunication Network |
| ATO | Air Traffic Operations Service |
| AWG | Aircraft Working Group |
| CAASD | Center for Advanced Aviation System Development |
| CAST | Commercial Aviation Safety Team |
| CATM | Collaborative Air Traffic Management |
| CAVS | CDTI Assisted Visual Separation |
| CDA | Continuous Descent Arrival |
| CDROM | Compact Disc Read-only Memory |
| CDTI | Cockpit Display of Traffic Information |
| CEFR | CDTI Enhanced Flight Rules |
| CFIT | Controlled Flight into Terrain |
| CFR | Code of Federal Regulations |
| CM | Configuration Management |

| | |
|---|---|
| CMU | Communications Management Unit |
| CNS | Communication Navigation and Surveillance |
| COI | Community of Interest |
| CONOPS | Concept of Operation |
| CPDLC | Controller Pilot Data Link Communications |
| CSPA | Closely-Spaced Parallel Approach |
| CSS | Cooperative Surveillance System |
| CTA | Controlled Time of Arrival |
| DS | Delegated Separation |
| D-TAXI | Data Link TAXI |
| EFB | Electronic Flight Bag |
| EFIS | Electronic Flight Instrument Systems |
| EFVS | Enhanced Flight Vision Systems |
| EN | Enabler |
| ERAU | Embry-Riddle Aeronautical University |
| ETA | Estimated Time of Arrival |
| FAA | Federal Aviation Administration |
| FANS | Future Air Navigation System |
| FCM | Flow Contingency Management |
| FDMS | Flight Deck-Based Merging and Spacing |
| FIS-B | Flight Information Service-Broadcast |
| FL | Flight Level |
| FMC | Flight Management Computers |
| FMS | Flight Management Systems |
| FOC | Flight Operations Center |
| FAROA | Final Approach Runway Occupancy Alerting |
| FMC | Flight Management Computers |
| FY | Fiscal Year |
| GA | General Aviation |
| GBAS | Ground Based Augmentation System |
| GE | General Electric |
| GLONASS | Global Navigation Satellite System (Russia) |
| GLS | GPS Landing Systems |
| GNSS | Global Navigation Satellite System |
| GOMEX | Gulf of Mexico |
| GPS | Global Positioning System |
| GRAS | Ground-based Regional Augmentation System |
| GSE | Ground Support Equipment |

| | |
|---|---|
| HMI | Human-Machine Interface |
| HMMH | Harris Miller Miller & Hanson Inc. |
| HUD | Head Up Display |
| IA | Initial Approach |
| ICAO | International Civil Aviation Organization |
| ID | Identification |
| IFR | Instrument Flight Rules |
| IIFD | Integrated Intelligent Flight Deck |
| ILS | Instrument Landing System |
| IMC | Instrument Meteorological Conditions |
| IPSA | Interagency Portfolio and System Analysis |
| IRAC | Intelligent Resilient Aircraft Control |
| IVHM | Integrated Vehicle Health Management |
| IWP | Integrated Work Plan |
| JIMDAT | Joint Implementation Measurement Data Analysis Team |
| JPDO | Joint Planning and Development Office |
| LNAV | Lateral Navigation |
| LPV | Localizer Performance with Vertical Guidance |
| LSA | Light-sport aircraft |
| LTA | Lighter than air |
| LV | Low Visibility |
| MDCRS | Meteorological Data Collection and Reporting System |
| MEA | Minimum En Route (IFR) Altitude |
| MEM | Memphis |
| MFD | Multifunction Display |
| MMC | Marginal Meteorological Conditions |
| MT | Mid-Term |
| MVA | Minimum Vectoring Altitude |
| NARP | National Aviation Research Plan |
| NAS | National Airspace System |
| NASA | National Aeronautics and Space Administration |
| NASEA | National Airspace Enterprise Architecture |
| NextGen | Next Generation |
| NGIP | Next Generation Implementation Plan |
| NIP | NextGen Implementation Plan |
| NOTAM | Notice to Airmen |
| NPRM | Notice of Proposed Rulemaking |
| NT | Negotiated Trajectory |

| | |
|---|---|
| OC | Operational Capability |
| OE | Operational Errors |
| OEP | Operational Evolution Partnership |
| OI | Operational Improvements |
| PANS | Procedures for Air Navigation Services |
| PARC | Performance Based Aviation Rulemaking Committee |
| PBN | Performance Based Navigation |
| PFD | Primary Flight Display |
| PRP | Published Routes and Procedures |
| RAA | Regional Airline Association |
| RAAS | Runway Awareness and Advisory System |
| RAMP | Ramp Manager |
| RBA | Risk Benefit Analysis |
| R&D | Research and Development |
| RF | Radius to Fix |
| RNAV | Area Navigation |
| RNP | Required Navigation Performance |
| RTA | Required Time of Arrival |
| RTCA | Radio Technical Commission for Aeronautics |
| RVR | Runway Visual Range |
| SAAAR | Special Aircrew and Aircraft Authorization Required |
| SAFE | Safety Enhancement/Hazard Avoidance & Mitigation |
| SATCOM | Satellite Communications |
| SBAS | Space Based Augmentation System |
| SBS | Surveillance and Broadcast Services |
| SESAR | Single European Sky ATM Research Programme |
| SEVEN | System Enhancement for Versatile Electronic Negotiation |
| SID | Standard Instrument Departure |
| SM | Separation Management |
| SOC | Systems Operations Center |
| STAR | Standard Terminal Arrival Routes |
| SUA | Special Use Airspace |
| SVS | Synthetic Vision Systems |
| SWIM | System-Wide Information Management |
| TAA-Piston | Technically-Advanced piston GA Aircraft |
| TAWS | Terrain awareness and warning system |
| TBD | To Be Determined |

| | |
|---|---|
| TBO | Trajectory Based Operations |
| TCAS | Traffic Alert Collision and Avoidance System |
| TFR | Traffic Flow Restrictions |
| TIS-B | Traffic Information Service - Broadcast |
| TM | Traffic Management |
| TSO | Technical Standard Order |
| UAPO | Unmanned Aircraft Systems Program Office |
| UAS | Unmanned Aircraft System |
| UAT | Universal Access Transceiver |
| US | United States |
| VDL-2 | VHF Digital Link Mode 2 |
| VDR | VHF Digital Radio |
| VFR | Visual Flight Rules |
| WAAS | Wide Area Augmentation System |
| VHF | Very High Frequency |
| VMC | Visual Meteorological Conditions |
| VNAV | Vertical Navigation |