Federal Aviation Administration

Appendix A

NextGen Investments for Operators and Airports

NextGen Implementation Plan, March 2011

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Appendix A NextGen Investments for Operators and Airports

NextGen system benefits depend on FAA ground-based systems, space-based systems, alternative fuels to reduce environmental impact, advanced avionics capabilities and airport infrastructure. This appendix outlines the opportunities for investment by operators and airports. It provides an overview of current and planned capabilities and relates them to the benefits that they enable.

This appendix uses enablers – Automatic Dependent Surveillance-Broadcast (ADS-B) Out or Localizer Performance with Vertical Guidance (LPV) avionics, for example – to describe the technologies required for an aircraft and operator, or an airport, to implement a NextGen capability. Each enabler is defined by a set of performance and functional requirements that allow market flexibility whenever possible. We guide operators in satisfying these requirements and deploying the enablers through Advisory Circulars (ACs) and Technical Standard Orders (TSOs). The enablers are linked to operational improvements that provide benefits and build on capabilities already installed or available for today's aircraft. This appendix provides an overview of the major categories of enablers for operators and airports.

Three different areas are targeted for aircraft operators: aircraft avionics; flight planning and routing support systems; and fuels and engines. Airports also will be an active participant in deployment of some improvements. For other improvements, such as ADS-B in the terminal area, the deployment of the system will take place without substantial actions by airports.

For each enabler, icons provide a quick look at key information, including:

- Target Users: The target users for each enabler can include air transport, business jet, general aviation

Icon Legend	
Target Users	Air Transport
	Business Aviation
	General Aviation
	Rotorcraft
Target Areas	Nationwide
	Metroplex Areas or Major Airports
	Oceanic
Maturity	Available
	In Development
	In Concept Exploration

fixed-wing and rotorcraft. These categories of target users represent generalized modes of operation and may not apply exactly to every civil or military operator. The FAA does not limit the NextGen capabilities to these targeted users groups. In addition to the specified user groups, some users may still find it worthwhile to invest in a particular enabler in order to meet their specific operational objectives.

- Target Areas for Implementation: The general strategy for deployment can include nationwide, in oceanic areas or in metroplex terminal areas with large and medium hub airports and satellite airports.

- Maturity: An enabler may already be available for operator investment, in development (including standards development) or in concept exploration.

Tables throughout this appendix summarize the enablers. A description of each enabler can be found in *NextGen Operator and Airport Enablers,* a supplement to this appendix that is available at www.faa.gov/nextgen. Additional detail concerning the operational improvements, and the FAA implementation plan for each improvement, is provided in Appendix B. ADS-B Out capability is the only enabler selected as a mandatory capability for all aircraft in a given airspace. It will be required in designated airspace on Jan. 1, 2020.

In addition to expanding the scope of this appendix from last year's plan, there are several changes in schedule, notably:

- Surface Indications and Alerts: Deferred in concept exploration due to technical challenges receiving the ADS-B messages on the airport surface.

- Deconfliction guidance: Deferred in concept exploration due to need for further definition of the operational concept, including integration with trajectory operations.

- Data Communications: Aligned the third version of domestic data communications (Aeronautical Telecommunications Network Baseline 3) with European plans.

- Ground Based Augmentation System Landing System (GLS) III: Deferred in concept exploration due to operational challenges in fielding the Category I system and the need to align the schedule with an aircraft program.

PERFORMANCE BASED NAVIGATION

Performance Based Navigation (PBN) encompasses a set of enablers with a common underlying capability to construct a flight path that is not constrained by the location of ground navigation aids. There are varying performance and functional requirements in the PBN family, from the 10 nautical mile (nm) course width accuracy and few waypoints required by Required Navigation Performance (RNP) 10 to the 0.1 nm precision and curved paths of RNP 0.1 Authorization Required (AR) approaches. For oceanic en route navigation, RNP 10 and RNP 4 will continue to be the standards. Domestically, Area Navigation (RNAV) 2 provides the required capability en route.

RNAV 1 is the mainstay in the terminal area, except where obstacles or airspace conflicts demand the improved performance provided by RNP 1. To achieve access to runways during limited visibility (instrument conditions), three capabilities offer different advantages and costs. The most basic, RNP 0.3, is a conventional non-precision approach capability that can be achieved with GPS alone. Vertical guidance can be added with either barometric Vertical Navigation (VNAV), or with a Satellite Based Augmentation System (SBAS). A basic VNAV capability can be used with RNP 0.3, and tighter Lateral and Vertical Performance can provide access to RNP AR approaches. The lowest approach minima are typically offered by LPV, which provides a satellite-based equivalent to conventional Category I Instrument Landing Systems (ILS).

Overview of Aircraft Operator Enablers						
Avionics Enablers	Aircraft and Operator		Capability Overview	Target Users	Target Area	Maturity
	Guidance	Schedule				
Performance Based Navigation						
RNP 10	Order 8400.12A	Complete	Reduced oceanic separation			
RNP 4	Order 8400.33	Complete	Further reduced oceanic separation (in conjunction with FANS 1/A)			
RNAV 1, RNAV 2	AC 90-100A	Complete	Ability to fly on more efficient routes and procedures			
RNP with Curved Path	AC 90-105	Complete	Ability to precisely fly departure, arrival and approach procedures including repeatable curved paths			
Vertical Navigation	AC 90-105, AC 20-138A	Complete	Ability to fly defined climb and descent paths			
LPV	AC 20-138B	Complete	Improved access to many airports in reduced visibility, with an approach aligned to the runway			
RNP Approaches (Authorization Required)	AC 90-101	Complete	Improved access to airports in reduced visibility with an approach that can turn to the runway; improved procedures to separate traffic flows			

The current aircraft fleet is well equipped with PBN capability. For example, in the air transport community, the heart of the PBN capability is the Flight Management System (FMS). The FMS uses input from the Global Navigation Satellite System (GNSS) – either GPS or Wide Area Augmentation System (WAAS) sensor – or multiple Distance Measuring Equipment (DME). DME has coverage limitations, and will not be supported on every published procedure. Most FMS installations can support RNAV operations and RNP with curved path, but less than half can support RNP AR approaches. LPV requires a WAAS receiver and integration with the displays.

In the general aviation community, the PBN enablers are typically implemented in a GNSS navigator installed in an aircraft's instrument panel. These systems have become increasingly complex and capable, integrating other types of navigation, voice communication and uplinked weather information. Most of these installations can support RNAV, and those equipped with WAAS can support LPV. Some of these configurations have fully implemented RNP with curved path or RNP AR approach capability and others may be upgradeable to RNP with curved path capability.

The primary equipage strategy for the PBN enablers has been operational incentives; aircraft that equip obtain a direct efficiency and access benefit because of the new routes, procedures and approaches. However, in some instances the new route or procedure cannot be designed or used optimally because of the need to accommodate traffic that is not equipped with these enablers. In addition, the legacy ground infrastructure for navigation will not be fully replaced, so a further incentive for PBN capability will come through the reduction of services to the non-equipped aircraft.

AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST

There are many different ADS-B enablers, with different cost and benefit implications. The most basic participation with ADS-B is ADS-B Out, where the aircraft's position and certain other data are broadcast by avionics. Ground receivers and other aircraft within range can receive these broadcasts and use them for their own applications. ADS-B Out enables the next generation of air traffic surveillance. Using ground receivers across the country, controllers will receive and process precise ADS-B broadcasts to provide air traffic separation and advisory services.

Building on the ADS-B Out capability, ADS-B avionics can be integrated with different controls and displays to implement ADS-B In enablers. The most basic types of enablers provide enhanced situation awareness, improving the ability of the flight crew to identify where aircraft are around them and the direction they are headed. This technology works in the air or on the ground, although the ground capability may be limited by coverage issues and the availability of quality airport surveys (see the airport enabler table below). This basic type of display is referred to as a Cockpit Display of Traffic Information (CDTI). A CDTI may be a new display, or it may be integrated with a conventional Traffic Alert and Collision Avoidance System (TCAS) traffic display.

Overview of Aircraft Operator Enablers						
Avionics Enablers	Aircraft and Operator		Capability Overview	Target Users	Target Area	Maturity
	Guidance	Schedule				
Automatic Dependent Surveillance-Broadcast						
ADS-B Out	AC 20-165	Complete	Enables improved air traffic surveillance and automation processing			
Airborne/Ground CDTI (ADS-B In)	AC 20-172, TSO-C195	Complete	Improved awareness of other traffic			
Surface Indications/Alerts (ADS-B In)	AC, TSO	2014	Displays and provides alerts based on non-normal traffic status			
In-Trail Procedure (ITP) (ADS-B In)	Policy Memo	Complete	Oceanic in-trail climb/descent			
	AC, TSO	2011				
Interval Management (ADS-B In)	AC, TSO	2012	Display of along-track guidance, control and indications, and alerts			
Airborne-CDTI with Conflict Detection (ADS-B In)	AC, TSO	2014	Displays and alerts crew to airborne conflicts independent of TCAS alerting			
Paired Parallel Approach Guidance and Alerting (ADS-B In)	AC, TSO	2014	Guidance information for aircraft participating in paired approaches to closely spaced runways			

Another set of ADS-B In enablers uses the ADS-B data for speed or timing guidance, typically maintaining spacing or separation from another aircraft. This includes both algorithms for oceanic In-Trail Procedures (ITP) and display of along-track guidance cues for interval management. Beyond these lie advanced alerting to improve airport safety and reduce the risk of collision for aircraft without TCAS. Eventually, ADS-B integrated with other capabilities is expected to support all-weather access to closely spaced runways and to enable airspace with self-separation similar to visual operations today.

The equipage for ADS-B is just beginning, with rule-compliant ADS-B equipment gaining approval in late 2010.

In air transport aircraft, ADS-B is expected to be implemented as upgrades to the Mode S transponder and aircraft displays. This equipment can be upgraded or replaced to support ADS-B as well as their original function. The various ADS-B In capabilities reflect different levels of integration with the controls and displays in the cockpit. Situational awareness can be achieved with side-mounted displays that are not integrated, along-track guidance can be implemented with front-mounted displays that are not integrated, and longer-term capabilities will require integration with other navigation data in front of the flight crew.

For general aviation operating below 18,000 feet, ADS-B can be implemented through the transponder or through a new radio, called the universal access transceiver (UAT). The UAT also provides access to weather and other aeronautical data services provided by the FAA. ADS-B In capabilities are implemented in general aviation with displays similar to those in use by air transport.

The FAA mandated ADS-B Out equipage in most controlled airspace starting in 2020. The agency is encouraging operators to equip portions of their fleets with ADS-B before the nationwide rule goes into effect by providing early benefits. As the operators experience the operational benefits, they will have an incentive to accelerate and expand the ADS-B equipage to the rest of their fleet.

For air transport operators, this strategy uses memorandums of agreement to accomplish this goal, where each party provides in-kind contributions critical to the success of the project. Each agreement is unique, reflecting the specific operator's business model, route structure and existing avionics infrastructure, among other factors. For general aviation operators, deployment of Traffic Information Services-Broadcast (TIS-B) and Flight Information Services-Broadcast (FIS-B), uplinked over the UAT, will enhance benefits and motivation to equip. The FAA is also evaluating additional locations where surveillance may be provided through ADS-B.

In 2010, the FAA convened an Aviation Rulemaking Committee (ARC) to develop recommendations for the implementation of ADS-B In capabilities. The ARC is expected to complete a final report in 2012.

DATA COMMUNICATIONS

Data Communications were first deployed as part of the Future Air Navigation System (FANS) program. Boeing and Airbus developed integrated communication and navigation capabilities (FANS 1 and FANS A, respectively), providing a pilot-and-controller data link and the ability to autonomously send some data from the aircraft to the air traffic control (ATC) system through Automatic Dependent Surveillance-Contract (ADS-C). These new navigation and communication capabilities were primarily targeted to oceanic airspace, where they provided the greatest initial benefits, enabling a safe reduction in separation between aircraft from 100 nm to as low as 50 nm.

As the FAA moves forward with deploying a domestic ATC data link system, it is important to make use of the FANS capabilities already installed on many aircraft. As such, the domestic program will use an adaptation of FANS appropriate for high-density, surveilled environments through FANS 1/A+ over VHF Data Link (VDL) mode 2. These aircraft will be able to receive departure clearances and airborne reroutes.

A newer capability, called the Aeronautical Telecommunications Network (ATN), was developed through the International Civil Aviation Organization (ICAO) to provide a more universally capable and reliable ATC data communications system. The capability that will be needed for full participation in NextGen in continental U.S. airspace will be the third version, called ATN Baseline 3. The standards for this version are under development and are being harmonized internationally.

Two earlier versions of ATN provide interim capabilities. Europe has begun to implement ATN Baseline 1, which can be retrofitted into aircraft without modification of the navigation system. The FAA plans to implement ATN Baseline 2 with a larger set of operational capabilities, such as revised departure clearances, to provide greater incentive for retrofitting aircraft.

FANS 1/A for oceanic operations has already been adopted widely by the fleet of aircraft operating internationally. The implementation strategy for domestic ATC data communications is primarily based on providing operational incentives to equipped operators. The FAA is evaluating potential scenarios for best-equipped, best-served in which aircraft with this capability may receive more rapid or efficient reroutes during inclement weather.

LOW-VISIBILITY OPERATIONS

The FAA is supporting several different capabilities for operators who need to access an airport during low visibility – when the cloud ceiling is below 200 feet above the runway or the visibility is less than one-half surface mile. Enhanced Flight Vision Systems (EFVSs) provide the greatest level of access, enabling lower approach minima, regardless of the navigation aid or airport infrastructure, by enabling the flight crew to literally see through the clouds using the EFVS technology.

At many airports the FAA has approved the use of a heads-up display (HUD) on a precision approach to lower minima. While this capability does not provide the ubiquitous access of EFVS, it can be implemented in many aircraft at lower cost.

Another enabler is GLS. This program is researching the use of differential corrections to GPS to support Category II and III approaches. This capability will be the same as Category II and III ILS, without the need to restrict taxiing aircraft near antennas and at reduced cost to the FAA.

EFVS has been adopted by the high-end business community, while HUD has begun to spread to the air carrier fleet. The GLS program is still in research and

Overview of Aircraft Operator Enablers

Avionics Enablers	Aircraft and Operator		Capability Overview	Target Users	Target Area	Maturity
	Guidance	Schedule				
Data Communications						
FANS 1/A (Satcom)	AC 20-140A, AC 120-70B	Complete	Oceanic data communications and surveillance, transfer of communications			
FANS 1/A+ (VDL mode 2)	AC 20-140A, AC 120-70B	Complete	Expansion of FANS to domestic clearances			
ATN Baseline 2	AC 20-140B	2013	Clearances, terminal information			
	AC 120-70C	2014				
ATN Baseline 3	AC 20-140C	2015	Expansion of ATN to trajectory operations			

Overview of Aircraft Operator Enablers						
Avionics Enablers	Aircraft and Operator		Capability Overview	Target Users	Target Area	Maturity
	Guidance	Schedule				
Low-Visibility Operations						
HUD/ILS	Order	Complete	Reduced minima at qualifying runways			
EFVS	AC 20-167, AC 90-106	Complete	Uses enhanced flight visibility to continue approach below minimums			
GLS III	Project specific policy	2014	Autoland in very low visibility			
Avionics Safety Enhancements						
FIS-B	TSO-C157, TSO-C154c	Complete	Weather and aeronautical information in the cockpit			

development, but new aircraft are being manufactured with the basic capability to reduce the costs of transitioning from ILS when GLS is mature.

The low-visibility enablers are implemented through best-equipped, best-served incentives, so that aircraft with the capability can gain airport access when other operators cannot.

AVIONICS SAFETY ENHANCEMENTS

FIS-B provides ground-derived weather data to aircraft lacking airborne weather radar, and real-time National Airspace System (NAS) status information. These data are primarily intended to improve safety of operations for general aviation aircraft and are provided over the same UAT signals used for ADS-B.

EQUIPAGE LEVELS

The following table summarizes the current equipage levels of the mature avionics enablers among civil operators. These estimates are based on coordination with air transport operators and the annual FAA general aviation and air taxi survey. The high penetration of PBN enablers reflects the maturity of those capabilities, which have been delivered in various forms for over 10 years. Other enablers, such as ADS-B Out, are only recently available and have not been installed.

ENGINES AND FUEL TECHNOLOGIES

Alternative jet fuels research continues with the intent of approving a range of ASTM International-qualified "drop-in" fuels that reduce the carbon footprint of commercial aircraft operations without compromising safety or requiring changes in aircraft, engines or fuel supply infrastructure. Fischer Tropsch alternative fuels, made from a variety of feedstocks including sustainable biomass, blended with Jet A already are approved for commercial use by ASTM International. Blends of sustainable hydrotreated renewable jet (HRJ) alternative fuels are expected to be approved for use in 2011. We are beginning to test additional advanced alternative fuels in support of eventual approval. Operator investment is limited to purchasing alternative jet fuels and fuel blends as they become available in commercial quantities. Airlines already have signed agreements to do so.

Extensive research of unleaded aviation gasoline has not yet identified a drop-in replacement for leaded aviation gas. The deployment of new unleaded aviation gasolines may require modifications to the existing fleet of reciprocating-engine-powered aircraft.

Current Equipage Levels of Available Enablers		
Enabler	Air Transport	General Aviation
RNP 10	58%	<5%
RNP 4	58%	<5%
RNAV 1, RNAV 2	92%	80%
RNP with RF	57%	<5%
VNAV	45%	0%
LPV	<5%	30%
RNP AR	36%	<5%
ADS-B Out	0%	0%
Airborne/Ground CDTI	<5%	<5%
ITP	0%	0%
FANS 1A (Satcom)	36%	0%
FANS 1A+ (VDL mode 2)	12%	0%
HUD/ILS	15%	0%
EFVS	0%	<5%
FIS-B	0%	<5%

Overview of Aircraft Operator Enablers						
Enablers	Operator or Airport		Capability Overview	Target Users	Target Area	Maturity
	Guidance	Schedule				
Engine and Fuel Technologies						
Drop-In Renewable Jet Fuel	Modified ASTM specification	2011 2013 2015	Expansion of jet fuel specification to allow production via alternative processes and feedstocks			
Engine Efficiencies	Technology available for aircraft design	2015	Engine technology demonstrated with lower fuel burn, noise and emissions			

Some airframe and engine technologies may be retrofitted on existing aircraft in order to speed technology insertion. However, other technologies such as the high-bypass-ratio geared turbofan and open-rotor engines would only be expected on future generations of aircraft.

FLIGHT OPERATIONS CENTERS

Flight operations centers (FOCs) have a significant role in Collaborative Air Traffic Management (CATM) initiatives. The FOC could be specific to the operator (e.g., an airline) or a company providing value-added flight planning support. To fully participate in CATM, FOCs need to develop and maintain information technology systems to achieve three basic objectives: data connectivity to the FAA through Collaborative Information Exchange (CIX), processing of aeronautical status and weather information in flight planning software, and development of user-preferred routes. The FAA plans to implement a CIX to provide increased situational awareness and improved constraint prediction by incorporating data made available via System Wide Information Management (SWIM) mechanisms. Examples are Special Use Airspace (SUA) status and surface event information.

In the near term, the Flight Planning Services software will be enhanced to generate a prioritized list of trajectory options for each flight. These lists will be used by the FAA's Traffic Flow Management System (TFMS) to ensure that operator priorities are appropriately considered. These trajectory option sets can be forwarded to the TFMS when traffic management initiatives are issued due to volume or weather conditions. They can also be forwarded for reconsideration whenever operator flight priorities change.

AIRPORT ENHANCEMENTS

Airports are active participants in the implementation of NextGen across the NAS. While many investments in NextGen technologies are the responsibility of FAA or aircraft operators, airports will also have opportunities to advance NextGen.

PBN instrument flight procedures are a key component of NextGen because they can improve the efficiency of airport arrivals and departures. For general aviation operators and some regional air carriers, WAAS/LPV approach procedures can provide near Category I minimums. Business jet operators and air carriers are more commonly equipped for RNAV and RNP, which can support Category I minimums. The FAA may opt for an incremental phaseout of the ILS Category I installations by 2025, as both WAAS/LPV and RNAV/RNP provide for more cost-effective and flexible instrument approach procedures. In addition, in 2012-2014 the FAA will decide on the deployment of GBAS equipment, which is planned to provide Category II and III capabilities. As such, GBAS could augment or replace the existing ILS Category II and III installations at airports throughout the NAS.

Airports have the key role of discussing with their users the need for new or additional PBN procedures. A hub airport may serve air carriers that are actively seeking to expand the use of RNAV or RNP procedures, while a general aviation airport may benefit from a new WAAS/LPV approach procedure. An airport can request that the FAA initiate consideration and design of these procedures. Airports can facilitate the aeronautical survey, and obstruction-mitigation and runway-lighting actions that may be needed to achieve lower minimums. The surveys, obstruction mitigation and runway lighting could be eligible for Airport Improvement Program (AIP) funds.

Surface surveillance and management is another key area for airport involvement in NextGen. The FAA plans to complete deployment of Airport Surface Detection Equipment-Model X (ASDE-X) at 35 airports by 2013. Additionally, the agency aims to install enhancements to airport surface detection equipment at nine other airports by 2015. At these facilities, airports can install ADS-B squitters on airport-owned vehicles that regularly operate in the movement area. The squitters would broadcast vehicle positions to ATC, aircraft equipped with ADS-B In and the airport operations center. This would improve situational awareness and safety, particularly during construction

Overview of Airport Enablers						
Avionics Enablers	Operator or Airport Guidance		Capability Overview	Target Users	Target Area	Maturity
	Guidance	Schedule				
Airport Enhancements						
Geographic Information System	AC 150-5300-16,-17, -18	Ongoing	Detailed geospatial data on airports and obstructions			
ADS-B for Surface Vehicles	AC	2011	ADS-B squitter equipage for surface vehicles operating in the movement area	Airport rescue firefighting equipment, snowplows, inspection trucks		

projects and winter weather events. AIP eligibility for the ADS-B squitters is being evaluated.

FAA continues to research the need and technology options for non-movement area surface surveillance, particularly in support of NextGen surface traffic management concepts that are also still in development. For airports that will not receive ASDE-3/X, the FAA is also researching low-cost technologies and systems that could provide a surface surveillance capability.

Some airports have elected to install surveillance systems to complement ASDE-3/X and provide coverage of non-movement areas. Because airports are able to monitor operations on the airport surface more precisely, situational awareness is improved.

The FAA recognizes and appreciates the efforts of airports and vendors to develop systems and tools to improve surface situational awareness. To date, the results show substantial promise, but challenges with data sharing and dependencies have emerged. As a result, the FAA requests that airports considering investments in surface surveillance technologies coordinate with us in advance on system design – particularly for vendor systems that rely on FAA data sources such as ASDE-3/X. The FAA still is shaping the policy and processes to enable improved access to NAS data to support the emerging surface operational concepts under NextGen. We plan to streamline the approval processes to give aviation users access to NAS data through the new NAS Enterprise Services Gateway. With advance coordination, vendor systems can be designed with an architecture that is compatible with emerging FAA surface operational plans.

Because new runway and taxiway infrastructure is critical to capacity and efficiency, the continued transition of airport layout plans into the Airport Geographic Information System application will improve the airport planning process. The FAA is also proceeding with research to revise the separation standards for Closely Spaced Parallel Operations (CSPO) on parallel runways. The revisions to CSPO standards will be incremental throughout the mid-term and far-term periods to incorporate both existing and new technologies. An initial revision to the current 4,300-foot minimum separation for independent arrivals is planned for 2012 as a result of revisions to blunder standards and with use of existing technologies such as Dual ILS. Other revisions will follow and may be dependent on PBN and aircraft equipage. As revisions to CSPO standards become available, airports will be able to incorporate these improvements into their long-term planning. (Appendix B highlights the FAA's work on CSPO).