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Navigation Programs Strategy




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Preface

This Navigation Programs Strategy document contains the FAA's plan to provide navigation services to support FAA Strategic Priorities such as NextGen, the *Performance Based Navigation (PBN) National Airspace System (NAS) Navigation Strategy 2016*, and NAS Efficient Streamlined Services (NESS). This strategy is intended to inform the *Federal Radionavigation Plan* and is aligned to the International Civil Aviation Organization (ICAO) *Global Air Navigation Plan (GANP)*. It includes implementation of new capabilities, sustainment of current systems, and rationalization of systems recommended to right-size the existing NAS navigation infrastructure.

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Executive Summary

This Navigation Programs Strategy contains the FAA's plan to provide navigation services to support FAA Strategic Priorities such as NextGen, the *PBN NAS Navigation Strategy 2016,* and the NESS initiative. This strategy informs the *Federal Radionavigation Plan* and is aligned to the ICAO GANP. The key purpose of this Navigation Programs Strategy is to describe the enabling navigation infrastructure for the NAS transition to PBN and the rationalization of ground-based NavAids as part of a resilient navigation infrastructure to meet the safety, security, and the operational needs of the NAS.

For the past 60 years, navigation within the NAS has been based primarily on fixed routes and procedures enabled by conventional ground-based Navigation Aids (NavAids) originally fielded in the 1950s. The conventional system consists of single tracks between the NavAids that have worked effectively for many years. However, with increasing air traffic, the limitations of the conventional system have led to more frequent and significant delays and disruptions annually. In response to NextGen forecast estimates that air traffic will continue to increase in the years ahead, the FAA is transforming the NAS to PBN. PBN enables aircraft to fly flexible point-to-point routes and parallel tracks to reduce en-route chokepoints and delays. In terminal airspace, PBN enables aircraft to fly precise tracks that are closer together, allowing for more efficient use of the airspace while reducing noise, fuel consumption, and carbon emissions. The transition to PBN is being enabled, to a large extent, by the US Global Positioning System (GPS) and the FAA's Wide Area Augmentation System (WAAS) plus Aircraft Based Augmentation Systems (ABAS). GPS, WAAS, and ABAS are referred to collectively as Global Navigation Satellite System (GNSS). As an enabler of PBN, aircraft use GNSS to fly Area Navigation (RNAV) and Required Navigation Performance (RNP) routes and procedures virtually anywhere in the NAS, in all phases of flight. RNP and RNAV use a common navigation specification, except RNP requires aircraft-based monitoring to alert the pilot, when aircraft navigation performance is not meeting the level required for the intended PBN procedure. The onboard monitoring requirement enables aircraft to fly tighter flight paths to increase capacity and efficiency benefits at airports with high traffic density or challenging terrain. RNAV provides a general purpose point-to-point service that provides benefits at most locations. GNSS is vulnerable to outages caused by Radio Frequency Interference (RFI) jamming and spoofing; therefore, a portion of the ground-based NavAids will be retained to provide a resilient backup for GNSS.

The Distance Measuring Equipment (DME) provides an RNAV-capable backup to GNSS. Aircraft with scanning DME receivers and an Inertial Reference Unit (IRU) fly RNAV where sufficient coverage is available today. However, DME signal coverage has gaps that restrict DME use to aircraft that carry IRUs and only at locations where sufficient coverage is available.

The *PBN NAS Navigation Strategy 2016* identifies the need to enhance DME infrastructure to provide RNAV routes that allow aircraft (without IRUs) to fly in Class A airspace and at the busiest

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Navigation Service Group (NSG) 1-2 airports[1]. Because Very High Frequency (VHF) Omnidirectional Range (VOR) systems are not used for PBN, VORs can be reduced to a Minimum Operational Network (MON) through a rationalization process to provide a basic conventional navigation backup without DME RNAV during GNSS disruptions. Non-Directional Beacons (NDB) do not enable PBN, so this legacy equipment can also be considered for removal. Given the widespread implementation of RNAV (GPS) approach procedures with Localizer Performance with Vertical guidance (LPV) minimums, sustaining Instrument Landing Systems (ILS) can be rationalized to ensure systems needed to support safe recovery during GNSS disruptions are retained. The legacy NavAids that are retained, most of which are well beyond their service life, will need to be sustained to provide reliable services to the NAS.

This Navigations Program Strategy document comprises the following sections and will be reviewed approximately every three years to accommodate evolution of the NAS, development of PBN, and alignment to future missions and goals:

Section 1.0 describes the overall purpose of the Navigations Program Strategy
Section 2.0 provides an overview of conventional navigation and PBN
Section 3.0 describes the overall strategy objectives this document aims to achieve
Section 4.0 describes the overall navigation evolution for the Near-, Mid-, and Far-Term
Section 5.0 describes the strategy for Ground Based NavAids (GBNA) Programs
Section 6.0 describes the strategy for GNSS systems
Section 7.0 describes the strategy for Visual Guidance Lighting System (VGLS) Programs
Section 8.0 describes the strategy for sustainment
Section 9.0 describes the strategy for other navigation programs
Section 10.0 describes Navigation Program's innovations
Section 11.0 summarizes the Navigation Programs Strategy
Sections 12.0 – 17.0 provide appendices with supporting material such as references, acronyms, glossary, system quantities, NextGen Operational Improvements (OIs), and the NAS Enterprise Architecture (EA) Navigation Infrastructure Roadmap.

[1] *PBN NAS Navigation Strategy 2016*

1.0 Purpose

This Navigation Programs Strategy contains the FAA's plan to provide navigation services to support FAA Strategic Priorities such as NextGen, the *PBN NAS Navigation Strategy 2016,* and the NAS Efficient Streamlined Services (NESS) initiative. This strategy informs the *Federal Radionavigation Plan* and is aligned to the ICAO GANP.

Consistent with the *PBN NAS Navigation Strategy 2016*, this Navigation Programs Strategy spans the time period from 2017 to 2030 in three segments: Near-Term (2015-2020), Mid-Term (2021-2025), and Far-Term (2026-2030). This document addresses only FAA-owned and maintained systems. It includes implementation of new capabilities, sustainment of legacy systems, and rationalization of the NAS navigation infrastructure.

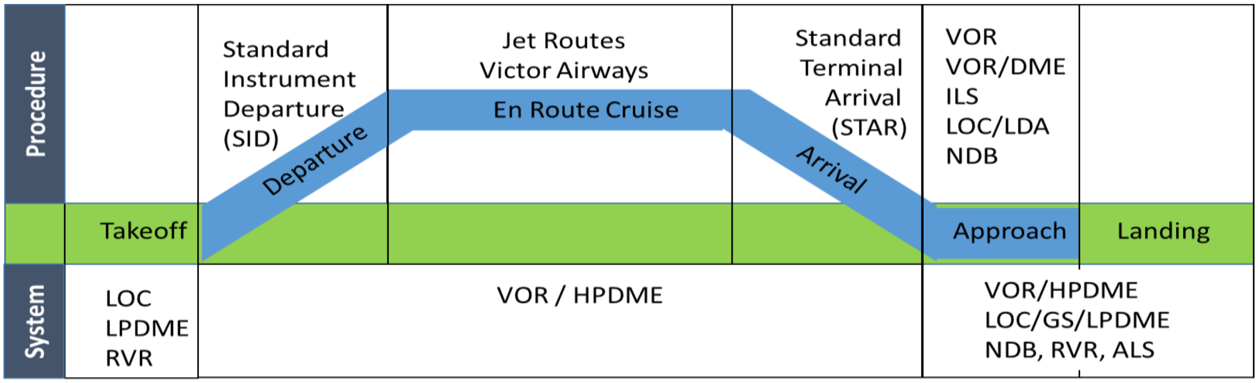
2.0 Introduction

Maintaining a safe and efficient structure of routes and procedures for thousands of aircraft traversing the skies over the United States in a highly technical, complex, and regulated environment is a significant challenge. Since 2006, the NAS has been transitioning from conventional navigation to PBN. PBN services provide capacity and efficiency benefits while reducing noise and carbon emissions through more precise and direct routings. PBN operations are enabled by GNSS (primary) and DME (secondary). Neither VHF Omni Directional Range (VOR) nor NDB enable PBN, so these conventional systems will be rationalized to provide a resilient backup when GNSS is unavailable.

2.1 Conventional Navigation

The conventional navigation infrastructure consists of routes and procedures enabled by several thousand VORs, DMEs, ILSs, and NDBs. **Figure 1** provides an overview of how conventional procedures and navigation system are utilized in the NAS by phase of flight. **Table 1** shows the current inventory of conventional navigation systems and procedures by phase of flight (consistent with Figure 1).

Figure 1: Conventional Navigation by Phase of Flight



In the future, navigation services will continue to be based on a combination of ground-based NavAids and GNSS for all phases of flight—although the number of ground-based NavAids will be reduced as part of a rationalization process. Navigation is a key element of this transformation, one that directly enables many NextGen Operational Improvements (OIs), as shown in Appendix D.

Table 1: Conventional Navigation Infrastructure (as of March 2, 2017)

Ground-Based NavAids Systems		Flight Phase	Conventional Procedures	
VOR TACAN NDB	954 469 166	Departure	Standard Instrument Departure (SID)	1,067
		En-Route	Jet Route	277
			Victor Airway	668
		Arrival	Standard Terminal Arrival (STAR)	1,061
		Approach	VOR	1,094
			TACAN	582
			VOR/DME	861
			NDB	542
Localizer (LOC only)	128		LOC	1,753
ILS (GS and LOC)	1,139		ILS (Category-I)	1,552
			ILS (Category-II)	158
			ILS (Category-III)	119
Total	**2,856**		**Total**	**9,734**

2.2 Performance Based Navigation

In the early 1990s, advances in satellite navigation technology allowed for civil aviation use of GPS, providing the foundation for seamless navigation worldwide. RTCA, Inc., developed standards for supplemental use of GPS in 1991. In 2003, the FAA commissioned the WAAS to augment GPS and provide a primary navigation service for all phases of flight. The FAA also led the implementation of PBN and published, in 2006, the *Roadmap for Performance Based Navigation* that outlined the strategy to transition the NAS to PBN.

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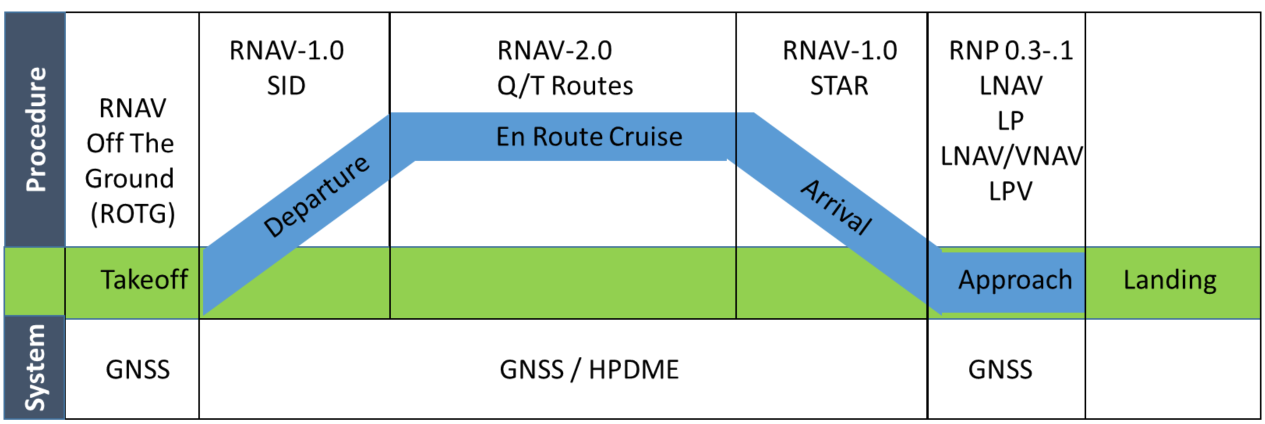
Unlike conventional VOR and ILS navigation, PBN specifies a level of performance required to fly an instrument flight procedure (IFP) independent of specific sensors. PBN operations consist of two specifications:

- Area Navigation (RNAV): A navigation specification for point-to-point navigation, designated by the prefix RNAV (e.g., RNAV-Pro)
- Required Navigation Performance (RNP): A navigation specification based on RNAV plus aircraft-based monitoring to alert the pilot when navigation performance is not acceptable for the intended IFP, designated by the prefix RNP (e.g., RNAV 2)

The RNAV and RNP specifications include accuracy and containment requirements expressed as a radius in nautical miles (NM). The accuracy value is one times (1X) the RNAV/RNP value, and containment is two times (2X) the value. For accuracy, an aircraft on an RNAV 2 route must stay within two NM of the centerline ninety-five percent of the time. For containment, the aircraft must not exceed four NM from centerline, for a route width of 8 NM. RNP routes are similar to RNAV in that they are linear but the monitoring and alerting capabilities that come with RNP enable narrower route widths.[2]

PBN specifications are defined at the aircraft level, including the navigation system error (NSE) and pilot performance or flight technical error (FTE). NSE includes avionics and ground system errors expressed as accuracy, availability, integrity, continuity, and coverage. Navigation performance standards are developed collaboratively through the work of standards organizations such as RTCA, ICAO, and Air Navigation Service Providers (ANSP). **Figure 2** below depicts how PBN is being implemented in the NAS.

Figure 2: PBN Implementation in the NAS



During takeoff, RNAV-Off-The-Ground (ROTG) is implemented at qualifying locations where benefits can be obtained.

[2] RTCA/DO-236, Minimum Aviation System Performance Standard for Required Navigation Performance for Area Navigation, June 19, 2013.

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For departure, RNAV Standard Instrument Departures (SID) are being implemented. Equivalent Lateral Spacing Operations (ELSO) is a capacity improvement tool implemented by publishing RNAV SIDs. RNAV SIDs are also used to implement Continuous Climb Operations (CCO) to maximize efficiency. RNAV SIDs use the RNAV 1 specification to establish 4-NM-wide routes.

RNAV Q and T Routes are being implemented during en-route cruising. Q Routes are published in high-altitude airspace Flight Level (FL) 180 and above. T Routes are low-altitude routes implemented below 18,000 Mean Sea Level (MSL). Q and T Routes use the RNAV 2 specification to establish 8-NM-wide routes. Q Routes can be flown with GNSS or DME, but T-Routes can be flown only with GNSS.

During arrival, RNAV Standard Terminal Arrival (STAR) procedures are being implemented using the RNAV 1 specification to establish 4-NM-wide routes. Continuous Descent Operations (CDO), are being implemented as Optimized Profile Descents (OPDs), in the United States as STARs with block altitudes to enable aircraft to descend at low power, thereby reducing noise, fuel consumption, and carbon emissions.

RNAV and RNP approach procedures are being implemented as Lateral Navigation (LNAV), RNP Authorization Required (AR), and Localizer Performance (LP) procedures provide two-dimensional guidance, while LPV, LNAV Vertical Navigation (LNAV/VNAV) procedures provide vertical-guided approach service. All PBN approach operations require GNSS.

Table 2 below depicts the current inventory of PBN procedures in the NAS. At this time, there are more than twice as many PBN procedures as conventional procedures.

Table 2: PBN Instrument Flight Procedures (as of March 2, 2017)

Flight Phase	PBN Procedures	IFPs
Departure	RNAV SID	1,189
En-Route	Q Route	146
	T Route	117
	TK Route (Helicopter)	2
Arrival	RNAV STAR	839
Approach	GPS Overlays	82
	Lateral Navigation (LNAV)	6,162
	Required Navigation Performance Authorization Required (RNP AR)	716
	Localizer Precision (LP)	635
	Lateral Navigation/Vertical Navigation (LNAV/VNAV)	3,669
	Localizer Precision with Vertical Guidance (LPV)	3,798
	Ground Based Augmentation System (GBAS) Landing System (GLS)	11
	Total	**17,366**

As the data above show, PBN implementation has progressed significantly over the past 10 years, especially in the approach phase where PBN procedures outnumber conventional VOR and ILS by a factor of nearly three to one (3:1). The majority of the PBN implementation that remains to be completed is for terminal and en-route operations.

3.0 Objectives

The Navigation Programs Strategy is guided by the NextGen Implementation Plan (NGIP), the *PBN NAS Navigation Strategy 2016*, and NESS initiatives. It also informs the *Federal Radionavigation Plan* and is aligned with the ICAO GANP. The Navigation Programs Strategy 2018 objectives address the focus areas and strategic initiatives listed in **Table 3**.

Table 3: Navigation Programs Strategy Goals based on Focus Areas and Strategic Initiatives

<table>
<tr><th>Focus Areas and Strategic Initiatives</th><th>Navigation Programs Strategy Goal</th></tr>
<tr><td colspan="2">PBN NAS Navigation Strategy 2016</td></tr>
<tr><td>Operate with PBN throughout the NAS, using the right procedure to meet the need</td><td rowspan="2">Provide navigation infrastructure to enable implementation of PBN throughout the NAS
○ The WAAS and GPS programs provide GNSS services to enable PBN operations throughout all phases of flight throughout the NAS</td></tr>
<tr><td>Use navigation infrastructure where beneficial and flexibility when possible</td></tr>
<tr><td>Deliver and use resilient navigation services</td><td>Deliver resilient navigation services to maintain safety, capacity, and efficiency
○ Implement the NextGen DME Program to provide RNAV coverage for en-route and terminal airspace to provide a resilient backup to enable aircraft without IRUs to continue PBN operations during GNSS disruptions
○ Define requirements for a Satellite Operations Coordination Concept (SOCC) position at the FAA's Air Traffic Control System Command Center to manage real-time information on the NAS navigation status</td></tr>
<tr><td>Innovate and continuously improve</td><td>Innovate and improve Positioning, Navigation, and Timing (PNT) services to enable new capabilities
○ Develop harmonized standards for future Multi-Constellation GNSS with Advanced Receiver Autonomous Integrity Monitoring (ARAIM) and dual-frequency SBAS
○ Continue supporting research to identify the best methodologies for Alternative Positioning, Navigation, and Timing (APNT)</td></tr>
<tr><td>Improve Low-Visibility Access</td><td>Implement Criteria for Special Authorization (SA) Category-I / 1800 Runway Visual Range (RVR) and SA Category-II for LPV</td></tr>
<tr><td colspan="2">NESS Initiative</td></tr>
<tr><td>Reduce the FAA's operations by creating a more efficient streamlined NAS</td><td>Implement the VOR MON Program</td></tr>
</table>

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Focus Areas and Strategic Initiatives	Navigation Programs Strategy Goal
ICAO Initiative	
Rationalization of Terrestrial NavAids	Rationalize the navigation infrastructure to reduce maintenance costs ○ Rationalize select ILS and DME systems
GNSS Evolution	Provide support to GBAS cost/benefit analyses
Navigation Initiative	
Sustainment of Navigation Infrastructure	Sustain the navigation infrastructure to meet NAS availability requirements, including: ○ GBNA: ILS, DME, VOR ○ VGLS: PAPI, REIL, RVR, ALS, LDIN ○ GNSS: WAAS
Innovate Navigation Systems	○ Replace incandescent light with Light Emitting Diode (LED) technology for VGLS. ○ Support operational approval activities for WAAS LPV Category-II/III enabled by Enhanced Flight Vision Systems (EFVS)

3.1 PBN NAS Navigation Strategy 2016

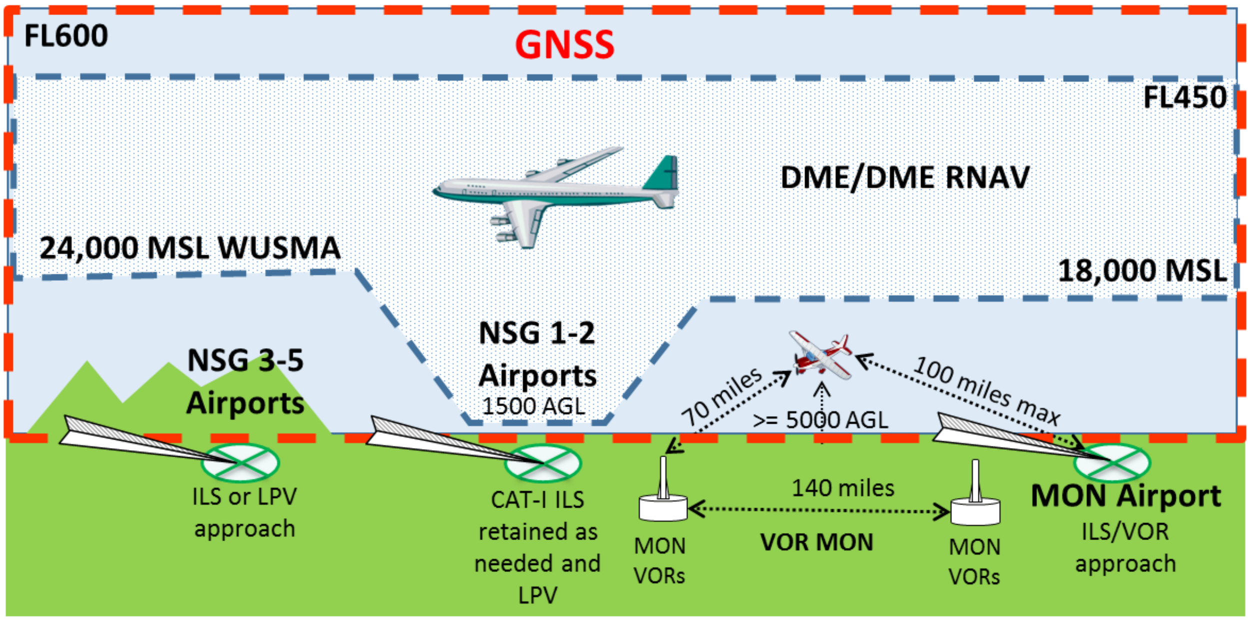
3.1.1 PBN throughout the NAS

PBN comprises RNAV and RNP and describes an aircraft's ability to navigate in terms of performance standards. RNAV enables aircraft to fly on any desired flight path within the coverage of ground or space-based navigation aids (within the capability of the aircraft equipage or several aircraft capabilities). Navigation Programs will make available the enabling PNT infrastructure so that PBN technology can be implemented with maximum benefits. Since GNSS (GPS, WAAS, and ABAS) is the primary enabler of PBN, Navigation Programs will continue to provide WAAS and GPS to enable PBN operations for all phases of flight throughout the NAS. The WAAS program will also continue to provide RNAV (GPS) approach procedures with LPV at all qualifying runways within the NAS.

3.1.2 Resiliency

Resiliency is the ability of the NAS to maintain safety and an acceptable level of service during system failure scenarios or degraded facility conditions while preventing or minimizing impacts to air traffic operations. Resiliency requires multiple services to be provided for the same capability at high-value locations and airspace, consistent with user equipage. Navigation Programs will implement a layered approach to ensure resiliency through a combination of GNSS and terrestrial NavAids. This approach is depicted in **Figure 3**.

Figure 3: Layered Approach for Resilient Navigation Services



The first layer is provided by GNSS, since it is the only navigation service to meet all RNAV and RNP specifications, and by Automated Dependent Surveillance-Broadcast (ADS-B) positioning requirements. The GNSS environment depicted in Figure 3 is the area within the red dashed line. Navigation Programs provides GNSS through its WAAS and GPS programs.

The second layer consists of DME RNAV without IRU to provide a resilient RNAV backup in Class A airspace and NSG 1 and select NSG 2 airports. In Figure 3, the DME RNAV environment is the area within the blue dashed line. Class A coverage is limited to 24,000 MSL and above over the Western US Mountainous Area (WUSMA), below which few routes are needed. If a GPS outage occurs, DME RNAV aircraft will continue flying to their NSG 1-2 destination, where an ILS or VOR approach can be flown for landing. The NextGen DME Program will optimize the DME network to provide DME RNAV coverage where needed to meet the objectives of the *PBN NAS Navigation Strategy 2016.*

The third layer consists of the VOR MON, which is used by aircraft not equipped for DME RNAV. The MON will ensure coverage at 5,000 feet Above Ground Level (AGL) to allow aircraft to fly through the outage area or to a MON airport no more than 100 miles away, where an ILS or VOR approach can be flown without DME.

ILSs support all layers of resiliency by providing precision approach guidance to the runway in all weather conditions regardless of whether GNSS service is available. Most runways with a Category-I ILS have an LPV with similar approach minima; however, in the event of a GNSS outage, the Category-I ILS will be unaffected and will continue to provide resiliency to landing aircraft. The ILS is the only system approved for Category-II/III approaches.

To manage real-time GNSS information for NAS navigation conditions, the FAA will define requirements for a SOCC at the FAA's Air Traffic Control System Command Center.

3.1.3 Innovation

The *PBN NAS Navigation Strategy 2016* strives to innovate and continuously improve technologies and procedures within the NAS. GNSS technology is advancing through the international deployment of new core constellations (i.e., Galileo and Beidou); as a result, new standards are needed for ARAIM using satellites from multiple core constellations and SBAS standards. Implementation plans must be developed for dual-frequency and multi-constellation GNSS. In a joint effort among multiple offices, the FAA will continue researching the best methodologies for APNT.

3.1.4 Low Visibility Access

To support the Improve Low Visibility Access Initiative in the *PBN NAS Navigation Strategy 2016*, Navigation Programs will assist in the implementation of criteria for SA Category-I with 1800 RVR and SA Category-II for LPV procedures.

3.2 NAS Efficiency and Streamlining Services (NESS) Initiative

To implement the MON, the VOR MON Program will discontinue unneeded VORs and reduce the number VORs by approximately 30%. This initiative can be accomplished because the NAS is transitioning to PBN, which does not require VORs. During a GNSS disruption, Non-DME-DME aircraft will revert to using the MON. The MON provides basic en-route and approach service to enable safe landing to a suitable destination. In addition, Category-I ILSs will be retained as needed to support safe recovery in the event of a GNSS outage. ILSs at MON airports will continue to use VOR for the initial, intermediate, and missed-approach segments while ILSs at airports without VOR will use DME RNAV.

3.3 International Civil Aviation Organization (ICAO) Initiatives

As the NAS completes the transition from conventional navigation to PBN, some of the NavAids will no longer be needed. ICAO has published details on the most effective way to rationalize terrestrial NavAids.[3] As described in Section 3.2, VORs do not support PBN, so, as part of the NESS initiative, the VOR MON Program will reduce the quantity of VORs. Although DME enables both conventional navigation and PBN, the DMEs not used for PBN can be rationalized during the transition to reduce operating costs and provide additional frequency assignments for new DMEs that will be installed to improve RNAV coverage. ILS will be retained to provide a safe recovery during GNSS disruptions, but some ILSs may be discontinued, such as those at airports where LPV is the primary approach being used.

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[3] ICAO Twelve Air Navigation Conference Paper, November 2012.

The GBAS augments GPS to provide an all-weather approach and landing capability. GBAS is an ICAO-compliant system designed to provide final approach guidance for Category-I/II/III precision approach and landing services by broadcasting differential GPS corrections, integrity information, and approach/departure path information via a VHF data link. The FAA completed regulatory approval of the Honeywell SLS-4000, Category-I system in 2009 as a non-Federal system. An FAA cost-benefit analysis for the GBAS is currently underway for a Category II/III capability in the NAS.

3.4 Navigation Initiatives

3.4.1 Sustainment of Navigation Infrastructure

When possible, the use of existing systems will be maximized through service life extension programs and through re-purposing spare parts from discontinued systems. However, replacement programs must be in place to ensure reliable suppliers are available to meet service availability demands. **Figure 5** on the following page illustrates the sustainment strategy for the systems only; it does not incorporate the programs which will be utilized to accomplish the sustainment work. Greater details on specific system sustainment activities can be found in Sections 5.0, 6.0, 7.0, and 8.0. Navigation Programs is developing a Navigation Portfolio to address the increasing sustainment needs of the aging legacy systems. The Navigation Portfolio will allow flexibility to adjust funding profiles to target systems with the greatest needs.

3.4.1.1 Sustain the GBNA infrastructure

The GBNA infrastructure, particularly VOR and DME, is well past its service life as depicted in **Figure 4**. Both VORs and DMEs will remain in the NAS for the foreseeable future to provide resiliency during GNSS disruptions; therefore, the FAA has begun an engineering study to determine which activities are necessary to sustain these infrastructures.

3.4.1.2 Sustain the Lighting Infrastructure

The VGLS infrastructure, particularly RVR, REIL, and MALSR, is well past its service life (depicted in **Figure 4**). The FAA is continuing to award procurement contracts for the installation of lighting systems across the NAS. Priority for sustainment is given to the oldest systems or the systems with the least reliable performance.

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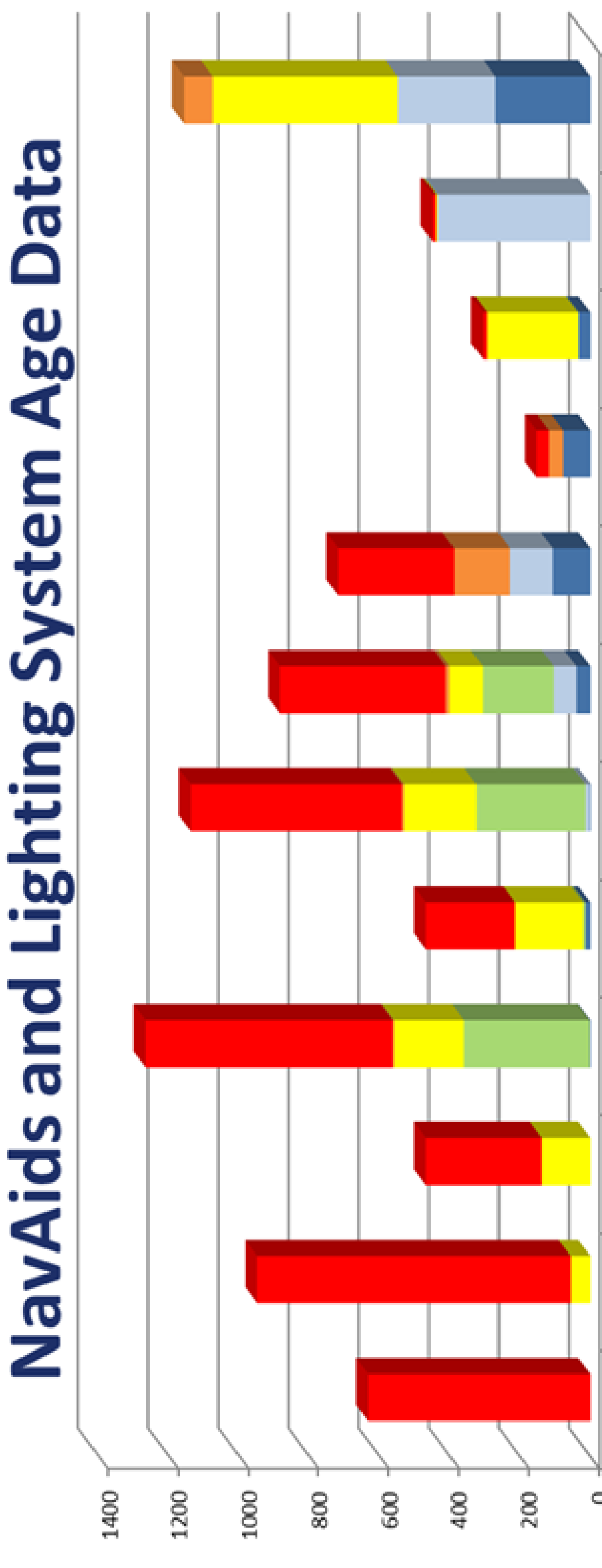
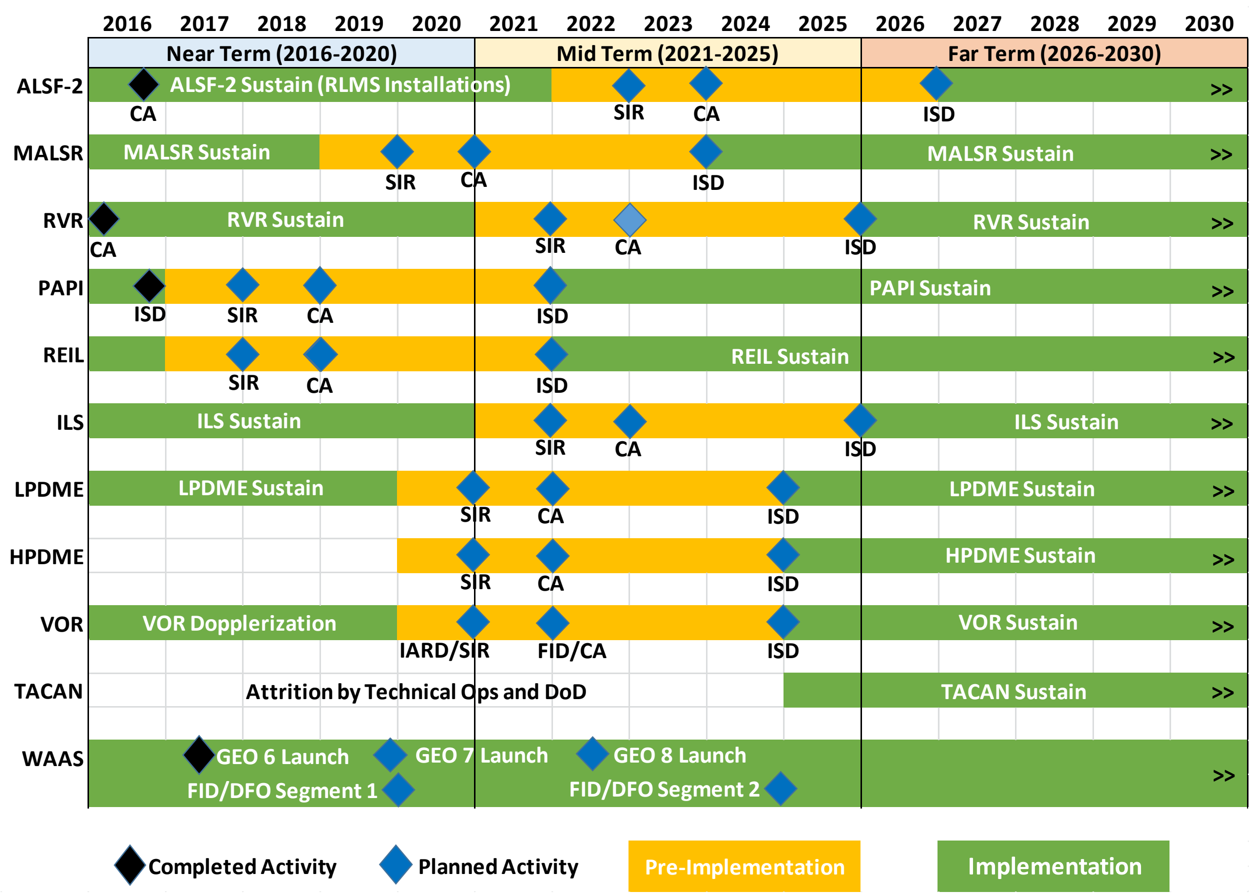
Figure 4 : NavAids and Lighting System Age Data (as of May 2017)



	VASI	VOR	TACAN	LOC	HP DME	GS	MALSR	REIL	ALSF	RVR	LP DME	PAPI
30+	633	898	331	703	255	602	471	329	35	11	9	
25-30				4		6	12	160	41			82
20-25		56	138	199	193	206	94			258	4	526
15-20				359	7	311	203			3		
10-15						12	64	122			437	280
<=10				2	14	2	40	107	77	33		270
Total	633	954	469	1267	469	1139	884	718	153	305	450	1158

Navigation Programs Strategy

Figure 5: Sustainment Strategy for NavAids, Lighting, and GNSS



IARD – Investment Analysis Readiness Decision **FID –** Final Investment Decision
SIR – Screening Information Request **ISD** – In-Service Decision **CA** – Contract Award

3.4.1.3 Sustain the GNSS Infrastructure

Navigation Programs will continue to sustain the WAAS geostationary (GEO) satellite constellation through the planned replacement of the existing three GEO satellites. The three new satellites are planned to be operational in 2018, 2019, and 2022, and each satellite's normal lifespan is 10 years. Other sustainment activities include the integration of a new safety computer and a G-III receiver, as well as the development and replacement of obsolescent system components such as the monitoring station and master station processors. These sustainment activities will be accomplished in a manner that does not degrade or interrupt current WAAS operations. Additional details on specific GNSS sustainment activities are provided in Section 6.0.

3.4.2 Innovate Navigation Systems

The transition from conventional procedures to PBN procedures increases predictability, reliability, and flight efficiencies while continuing to ensure safe operations. As PBN capabilities evolve, and emerging advancements in surveillance and communication become widely available in the NAS, it is vital that FAA and aviation stakeholders continue to innovate and integrate navigation technologies. For example, LED technology is being adopted for the REIL and MALSR systems to take advantage of significantly lower operating costs. In addition, as GNSS technology advances, the FAA will continue to explore the feasibility of achieving WAAS LPV Category-II/III. Navigation Programs is currently supporting the approval activities for WAAS LPV Category-II/III enabled by EFVS.

4.0 Navigation Evolution

The following sections provide an overview of the navigation evolution through the phases of the *PBN NAS Navigation Strategy 2016*. The figures in the following sections combine NavAid and IFP inventories throughout the Near-, Mid-, and Far-Term transition periods. In general, as NavAids are reduced, their associated IFPs will also be cancelled. However, the removal of conventional navigation systems can be dependent on the progress of PBN implementation. For example, discontinuance of VORs under the VOR MON Program can depend on the implementation of the PBN Route Structure (PBNRS) and removal of the conventional IFPs tied to the VORs. The following sections explain the applicable relationships for each strategy.

4.1 En-Route and Terminal Strategy

The primary enabler of PBN is GNSS[4] for all performance levels for en-route and terminal navigation. GNSS-equipped aircraft can fly the VOR airways and conventional SID/STARs, using RNAV substitution and the new RNAV and RNP procedures.

The NextGen DME and VOR MON Programs implement infrastructure changes to support the transition of terminal and en-route airspace to PBN. The NextGen DME program is needed to enable full implementation of RNAV SID/STARs at the NSG 1-2 airports and Q Routes in Class A airspace as part of the PBNRS, which, in turn, will facilitate removal of VORs, Jet Routes, Victor Airways, and conventional SID/STARs by the VOR MON Program. The strategy is depicted in **Figure 6**.

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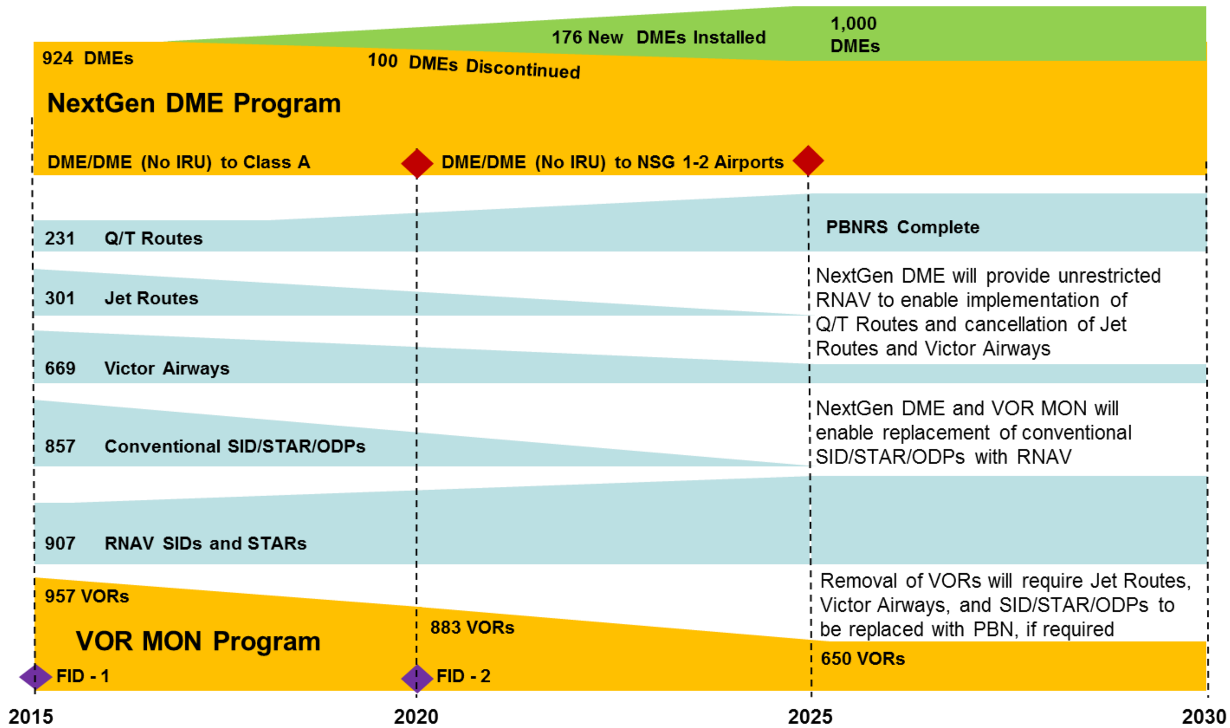
[4] WAAS and GPS with Receiver Autonomous Integrity Monitoring(RAIM)

Navigation Programs Strategy

Figure 6: En-Route and Terminal Strategy (as of March 2017)



The NextGen DME Program will add DMEs to enable DME RNAV for aircraft (without IRU) in Class A airspace and NSG 1 and select NSG 2 airports. The Program plans to install new DME systems, replace older DME systems with newer technology DMEs to increase their interrogation capacity, and target specific DMEs for rationalization. Implementation of the PBNRS concept will transform en-route airspace from conventional Victor Airways and Jet Routes to RNAV Q/T Routes. All Jet Routes and most Victor Airways are expected to be removed, while new Q/T Routes will provide route structure where needed. Elsewhere, aircraft will fly direct point-to-point without a static route structure.

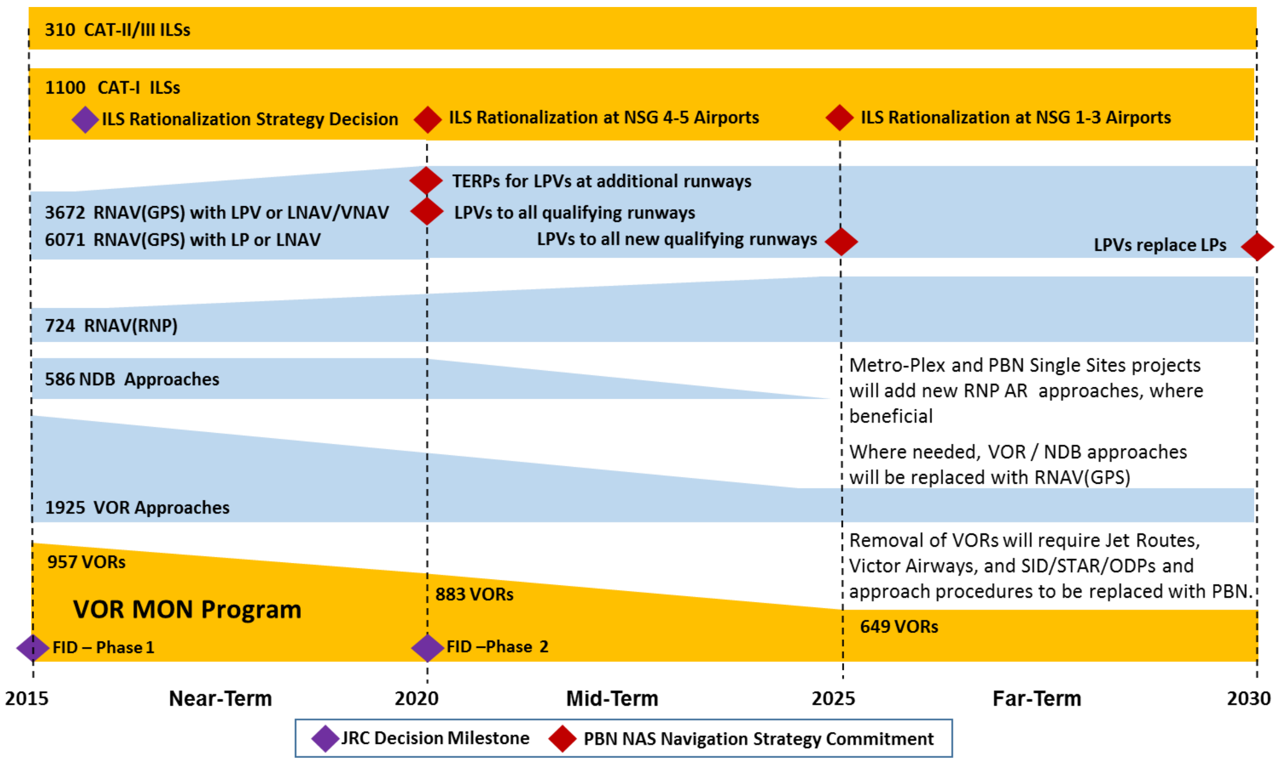
The VOR MON Program will discontinue approximately 308 VORs. As VORs are discontinued, their associated VOR airway segments will be cancelled without replacement, consistent with the *PBN NAS Navigation Strategy 2016*.

PBNRS will provide structure where needed, and direct point-to-point navigation will be used where structure is unnecessary. Most Jet Routes and Victor Airways in the WUSMA will be retained to enable aircraft to navigate safely through mountainous terrain during a GNSS outage. To meet the objective of minimizing conventional SID/STAR procedures, conventional SID/STAR procedures affected by discontinued VORs will be cancelled and/or replaced with RNAV SID/STARs.

4.2 Approach Strategy

The strategy for the approach phase of flight is focused on the implementation of RNAV (GPS) procedures and the reduction of VOR procedures. The strategy is depicted in **Figure 7** below.

Figure 7: Approach Strategy (as of March 2017). *Inventory numbers subject to change



The WAAS Program has been implementing RNAV (GPS) procedures with LPV minimums over the last 12 years. LPVs currently outnumber ILSs by a factor of nearly three to one (3:1). In 2017, LPV approaches will be available at the majority of qualifying runways in the NAS. LPVs will be used to provide new Category-I vertically guided service needs at most locations in lieu of establishing a new Category-I ILS approach. In the Near-Term, FAA Flight Standards will update the Terminal En-Route Procedures (TERPs) orders to allow additional runways to qualify for LPVs, which will bring vertically guided approach services to more airports.

The VOR MON Program is cancelling VOR approach procedures as VORs are discontinued. At airport runways where VOR is the only procedure, an RNAV (GPS) approach will be provided before cancelling the VOR procedure. Some VOR and ILS/LOC approaches will be retained as part of the VOR MON Program to provide a backup approach service at MON airports, in the event of a GNSS outage.

Category-I ILS approach service will be retained at selected sites to provide a safe recovery during GNSS disruptions. These include ILSs at VOR MON airports retained to provide a safe recovery for non-DME RNAV aircraft, as well as ILSs used for SA Category-I ELVO. ILS approaches retained at non-MON airports may be amended to use DME RNAV for portions of the procedure outside of the final segment. ILSs will be retained to support commercial aircraft at the busiest NSG 1-2 airports in the NAS. ILSs at NSG 3-5 airports may be considered for rationalization based on ICAO recommendations.

RNAV (RNP) AR approach procedures will be implemented by the Metro-Plex, Single Site, and Legacy Airspace Redesign programs.

NDB approach procedures will be targeted for cancellation. At locations where NDB is the only procedure at an airport, an RNAV (GPS) procedure will be provided before cancelling the NDB procedure.

5.0 Ground-Based NavAid Programs

As discussed in prior sections, the NAS is well on its way through the transition to PBN. This section provides a brief description of each NavAid, active programs under the Navigation Programs office, and the NavAid's future in the NAS.

5.1 Very High Frequency (VHF) Omnidirectional Range (VOR)

Figure 8: VHF Omnidirectional Range (VOR)

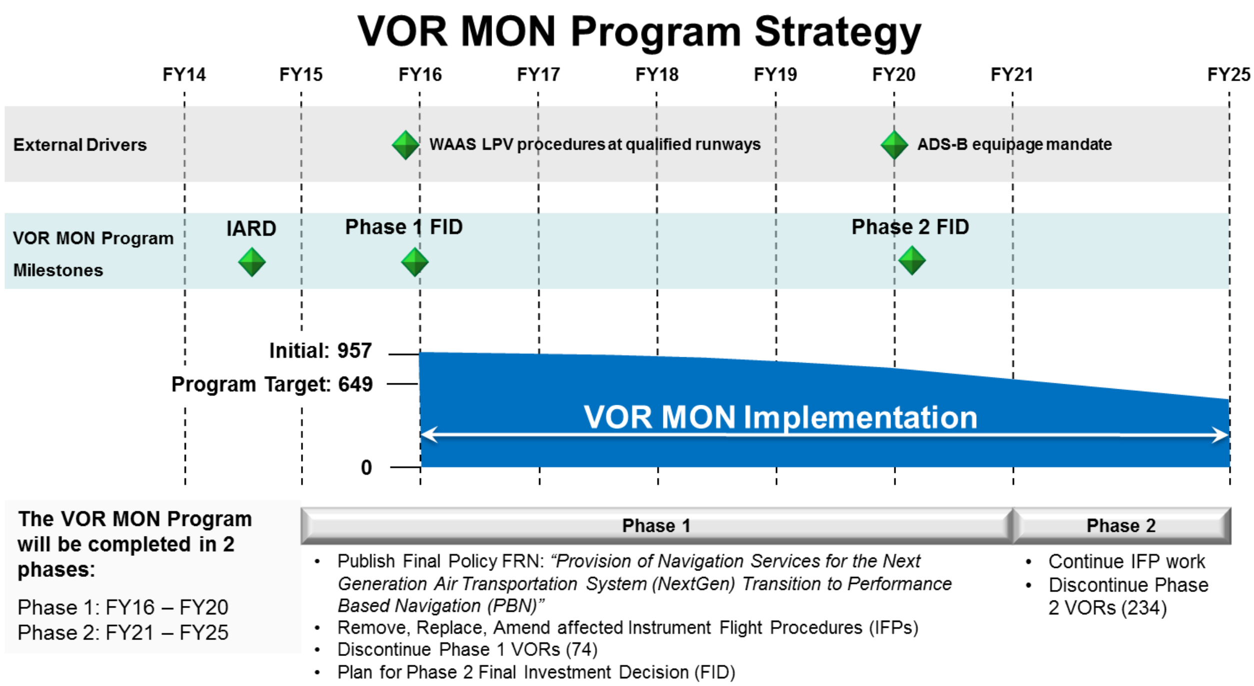
VORs are transmitters that have historically defined the US federal airways and supported non-precision (lateral guidance only) approach procedures. Introduced in the 1950s, VORs, shown in **Figure 8**, provide VHF electronic signals (108.0 MHz–117.95 MHz) to aircraft avionics that allow a pilot to determine the azimuth (i.e., direction/compass heading) the aircraft would have to fly to the VOR, or the azimuth the aircraft is flying away from a VOR. VORs have provided the backbone for en-route, terminal, and approach navigation for more than 60 years. VORs support the low-altitude Victor Airways, high-altitude Jet Routes, STARs, SIDs, and instrument approach procedures. VORs are also used to define Class B airspace sectors (i.e., a volume of airspace controlled by an air traffic controller). The FAA operates and maintains approximately 949 VORs and 100 VOR test (VOT) locations. More than 94% of VORs are over 25 years old (see Figure 4 in Section 3).

5.1.1 VOR Minimum Operational Network (VOR MON) Program

Because VORs are not used for PBN, the FAA plans to reduce the network to a MON by reducing approximately 30% of the facilities. The VOR MON Implementation Program will perform the work required to reduce the VOR network to approximately 650 VORs to provide a backup in the event of GNSS disruptions. Additionally, the program will expand the VOR Service Volume (SV) to an extended MON VOR Standard Service Volume (SSV) to meet coverage requirements. This backup network would allow aircraft not equipped with GPS to navigate and land under

Instrument Flight Rules (IFR). The VOR MON Program supports the NAS transition from the current VOR airways to PBN, consistent with NextGen goals. Prior to discontinuing a VOR, all associated IFPs must be cancelled, amended, or replaced. When VORs are discontinued, the co-located equipment will either remain in service or be relocated to a suitable location. The plan for the VOR MON program is depicted **Figure 9**.

Figure 9: VOR MON Program Strategy (as of January 2017)



5.1.2 VOR Dopplerization

There are numerous VORs that have signal restrictions due to encroachment of obstacles that block the transmission of VOR signals. These restrictions seriously impact en-route, arrival, and departure procedures. Natural encroachment happens when trees (located outside the boundaries of the FAA-controlled area where the VOR is located) have grown tall enough to cause interference to the VOR signal. Similar interference can be caused by many synthetic obstacles such as newly constructed tall buildings; nearby industrial parks with a high concentration of metal buildings; overhead transmission lines; towers for radio, television, and cell service; and wind farms. Dopplerizing a VOR eliminates the signal reflection restrictions caused by most of these obstacles. The FAA procures and installs Doppler VOR (DVOR) electronic kits and antenna kits to dopplerize a conventional VOR. While effective at eliminating signal interference, dopplerizing a VOR does not extend the service life of a VOR.

5.1.3 VOR Sustain

The FAA does not have an active contract to procure complete VOR systems; in fact, the agency has not procured VORs since the early 1990s. The VORs that remain in the NAS within the MON need to be sustained for the foreseeable future to provide a conventional backup during GNSS disruptions. A FAA engineering study has begun to determine what activities are necessary to sustain the VORs that will comprise the MON. Once a sustainment decision is made, the program plan will require approval through the FAA Acquisition Management System (AMS).

5.2 Tactical Air Navigation (TACAN)

Figure 10: Tactical Air Navigation (TACAN)

TACANs, as depicted in **Figure 10**, provide military aircraft with the same services civilian aircraft derive from VORs and DMEs. Although civilian aircraft cannot use its Ultra High Frequency (UHF) azimuth information, the TACAN's UHF distance measuring information is identical to that of a DME (but the TACANs use a slightly larger frequency band of 960 MHz–1,215 MHz). While the FAA supports military users through the operation and maintenance of TACANs in the NAS, these TACANs also support civilian DME requirements. Some TACAN components are more than 60 years old, and all are well beyond their 20-year service life. Although the FAA operates and maintains approximately 474 TACANs, which are collocated with a VOR to form a VORTAC facility, the FAA has not procured new TACANs since 1990. The DME function of TACANs located at VORTAC facilities is a critical part of the DME network used for RNAV. As the NextGen DME Program optimizes the DME network to fill coverage gaps and eliminate single-point failures, some of the VORTACs may need to be upgraded to increase the interrogation-reply performance. This may be problematic since the FAA does not currently have an approved source for new VORTACs.

5.2.1 TACAN Sustainment

There is no FAA procurement activity for TACANs at this time. All existing TACANs are beyond their service life and the FAA is commencing a sustainment plan. FAA Technical Operations is performing, in collaboration with the Department of Defense (DoD), an engineering study to determine which activities are necessary to sustain the TACANs. FAA Technical Operations is also working with the DoD to remove TACANs that do not support the mission. As shown in **Table 4**, 100% of TACANs are at least 20 years old, and some components are more than 50 years old.

Table 4: TACAN Age Data (as of May 2017)

TACAN	Age<=10	10<=15	15<=20	20<=25	25<=30	Age>30
Percent	0%	0%	0%	30%	0%	70%

5.3 Non-Directional Beacon (NDB)

NDBs, as shown in **Figure 11**, are transmitters that pilots can use with avionic direction-finding equipment (typically a receiver with a steerable loop antenna) to determine the azimuth of the aircraft to the NDB ground station. NDBs serve as non-precision approach aids at some airports; as compass locators, generally collocated with the outer marker of an ILS, to assist pilots in determining the step down fix to begin the descent to the Decision Altitude (DA) on the ILS course in a non-radar environment; and as en-route navigation aids. By determining the azimuth to at least two NDBs, a pilot can determine the aircraft position. Historically, NDBs were collocated with the Outer Marker (OM) and Middle Marker (MM), which changed their designation to a Locator Outer Marker (LOM) and Locator Middle Marker (LMM). LOM and LMM services have mostly been discontinued with the introduction of radar capabilities in terminal areas, but they are still used in non-radar areas in the NAS. The FAA still operates and maintains approximately 200 NDBs in Alaska. All the current NDBs are beyond their 20-year service life.

Figure 11: Non Directional Beacon (NDB)

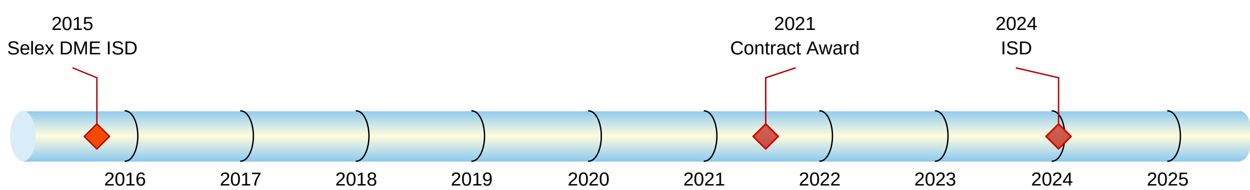
5.3.1 NDB Sustainment

There is no FAA procurement activity for NDBs at this time. NDBs are being gradually phased out of the NAS. No additional NDB approaches will be published, and NDB approaches used for training by the DoD or private entities will not be included in the NAS. By 2030, all NDB approaches are expected to be removed from the NAS.

5.4 Distance Measuring Equipment (DME)

A DME is a radio navigation aid used by pilots to determine the aircraft's slant distance from the DME location. Low-Power DMEs (LPDME) transmit 100 watts of power and are used for approach navigation, usually associated with an ILS. High-Power DMEs (HPDME) transmit 1,000-watts of power and are collocated with VORs to support en-route and terminal navigation. HPDMEs collocated with VORs allow aircraft to determine location on an airway during the en-route phase of flight. Aircraft equipped with scanning DME receivers can also range off of multiple HPDMEs (DME/DME) to fly RNAV procedures. The DME Program completed an In-Service Decision (ISD) in 2015 and a contract is in place to procure HPDMEs and LPDMEs. **Figure 12** depicts the DME Program schedule.

Figure 12: DME Program Schedule



5.4.1 NextGen DME Program

The overall objective for the NextGen DME Program is for DME/DME to provide a backup to enable aircraft to continue PBN operations during a GNSS disruption. Most commercial aircraft are equipped with GNSS and DME/DME avionics that can be used to continue flying RNAV procedures to their destinations and to an ILS or VOR approach (during a GNSS disruption). Under the

Navigation Programs Strategy

NextGen DME Program, the HPDME network will be enhanced to fill coverage gaps and eliminate single-point failures. Coverage gaps in the DME network limit DME/DME RNAV to those aircraft that also carry an inertial reference unit (IRU) enabling the aircraft to "coast" up to 33 miles through DME coverage gaps. Filling the coverage gaps with HPDMEs to a maximum of four miles will permit aircraft without IRU to fly RNAV.

Eliminating critical DMEs will prevent single DME failures from interrupting RNAV service for aircraft during GNSS disruptions as part of a resilient navigation infrastructure. A critical DME facility is one that, when unavailable, results in navigation service that is insufficient for DME/DME/IRU supported operations along a specific route or procedure.

The operational requirements for the NextGen DME Program are:

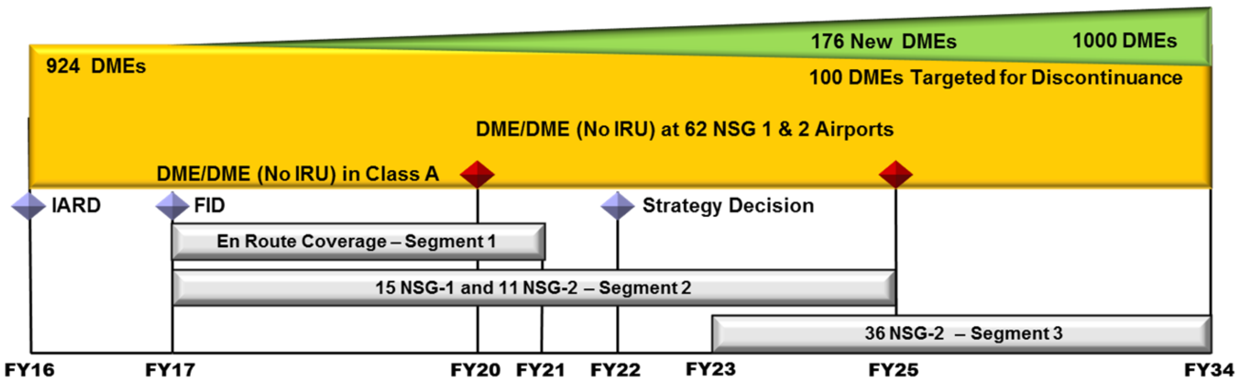
- Enable DME/DME aircraft (without IRU) to fly RNAV procedures in Class A airspace over Continental United States (CONUS)
- Expand DME/DME coverage (without IRU) providing RNAV 1 navigation down at NSG 1 and 2 airports to facilitate a conventional approach, as required (e.g., 1,500 feet Height Above Airport [HAA])

In order to achieve these requirements, the following activities will be accomplished:

- Expand the DME SV to widen coverage. Currently, HPDMEs are collocated with VORs and use the same SV, even though the actual DME signal coverage is significantly larger than the VOR SV.
- Install new DMEs to fill coverage gaps. The NextGen DME Program identified approximately 176 new DME installations necessary to fill the coverage gaps and redundancy.
- Upgrade existing DMEs, as required, to increase their interrogation capacity. Some older DMEs do not have the capacity to respond to all of the interrogations they receive (i.e., they become saturated). Traffic will continue to increase across the NAS, and it is imperative that DMEs not become saturated and deny DME/DME navigation service.
- Rationalize DME infrastructure to result in discontinuance of DMEs that are no longer needed. Approximately 361 of the existing DMEs are not required for RNAV. The NextGen DME program has targeted 100 DMEs to be discontinued from service.

The NextGen DME Program plan, DME quantities, and schedule information is provided in **Figure 13**.

Figure 13: NextGen DME Program Schedule (as of July 2017)



5.4.2 DME Establish and Sustain Programs

5.4.2.1 Low Power DME Establish and Sustain

LPDMEs, shown in **Figure 14**, are collocated with ILSs to support approach and landing by allowing an aircraft to determine its distance from the runway. LPDMEs will continue to be sustained across the NAS to replace the oldest systems with new technology that will increase their maintainability, reliability, and interrogation capacity. LPDMEs are being established across the NAS to replace Marker Beacons (MB) for ILS approaches as part of a Commercial Aviation Safety Team (CAST) initiative. The CAST initiative reduces the number of controlled-flight-into-terrain (CFIT) accidents at the most vulnerable locations in the NAS.

Figure 14: Low Power Distance Measuring Equipment (LPDME)

5.4.2.2 High Power DME Sustain Programs

HPDMEs will remain in the NAS for the foreseeable future to provide various navigation services in the en route and terminal environments. Navigation Programs is performing an engineering study to formulate a sustainment strategy for the HPDMEs. Once a sustainment decision is made, the program plan will require approval through the FAA Acquisition Management System (AMS) process.

5.5 Instrument Landing System (ILS)

ILS has been the mainstay for vertically guided approach service for more than 50 years, since the first facility was installed in 1938. The ILS provides both vertical and lateral guidance information for pilots to allow safe landings to touchdown and rollout. The ILS sends information to instruments in the cockpit so that the pilot can maintain a predetermined flight path to

Figure 15: Localizer Antenna (LOC)

the runway in low visibility. In addition, ILSs are used frequently under visual and night conditions to help pilots align to the runway centerline to improve safety.

An ILS consists of two separate facilities that operate independently but come together in the cockpit to enable both lateral and vertical precision guidance. An LOC, shown in **Figure 15**, transmits VHF signals (108.1 MHz to 111.95 MHz) to provide aircraft with lateral guidance that allows pilots to ensure their aircraft is properly aligned with the center of the runway during the approach and landing phases of flight. A Glide Slope (GS), shown in **Figure 16**, transmits UHF signals (329.15 MHz to 335.0 MHz) to provide aircraft with vertical guidance to enable a controlled descent as it approaches a runway. Working together, these two ILS facilities support a precision approach that ideally, depending on obstacles and terrain, allows aircraft to descend to a DA, at which time the pilot must visually recognize the runway environment and continue to a landing or execute a missed approach if the runway environment is not in sight.

Figure 16: Glide Slope (GS)

There are three categories of ILSs. Category-I ILSs provide guidance down to a DA of 200 feet above the runway. At locations where very low visibility conditions prevail, additional improvements to both the ILS ground system and aircraft avionics, as well as pilot training, can support lower DAs. Category-II ILSs provide guidance down to 100 feet DA, and Category-III ILSs can guide the aircraft to as low as touchdown (zero visibility), if the aircraft is equipped with an autoland system. The FAA operates approximately 1,180 ILSs; the DoD operates approximately 160 Category-I ILSs; and non-federal sponsors operate an additional 200 ILS facilities in the NAS. At some airports, obstructions prevent the installation of a glideslope to a runway. In these cases, only lateral guidance is provided by a LOC facility, when beneficial. There are 162 runway ends in the NAS where only lateral guidance is provided via a LOC.

5.5.1 ILS Sustainment Program

More than 70% of ILSs are beyond their 20-year service life. The ILS-420 procurement contract is in place to meet ILS sustain/establish requirements. The FAA procures systems to sustain Category-I ILSs at selected sites and to sustain and establish Category-II/III ILSs where needed. As the FAA transitions to PBN, ILS systems will continue to provide GPS-independent Category-I/II/III vertically guided approach services. The ILS is the only system currently approved for Category-II/III operations.

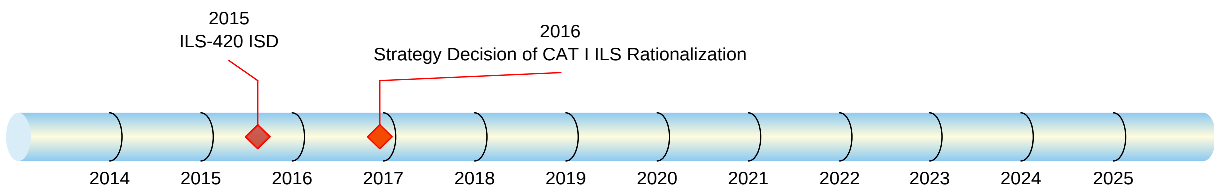
5.5.1.1 Category-I

Category-I ILS will be sustained by replacing approximately five new systems per year, when justified through a cost-benefit analysis. The FAA will not establish new Category-I ILSs because analysis shows that establishing an LPV approach is more cost beneficial.

5.5.1.2 Category-II/III

As required, new Category-II/III systems will be established and older systems replaced as part of sustainment. The program schedule for ILSs is provided in **Figure 17**.

Figure 17: ILS Program Schedule



5.5.2 ILS Rationalization Initiative

As the NAS transitions to PBN, GNSS technology has provided a more cost-effective alternative for vertically guided approach service. LPV procedures have been implemented since 2003 and now exceed ILSs by nearly double. The FAA has also elected to fulfill all new Category-I requirements for newly qualified runways with LPV procedures instead of ILSs. Therefore, consistent with the *PBN NAS Navigation Strategy 2016*, the FAA will rationalize the Category-I ILS inventory to ensure vertically guided instrument approach services are provided to the lowest practical minima at qualified instrument runway ends. Runway ends that currently have vertical guidance will retain vertical guidance, but it may be necessary to replace ILSs with LPVs, where beneficial. ILSs will be retained at VOR MON airports to provide a safe recovery during a GPS outage. Category-II/III ILSs and their associated Category-I procedures will be retained, as will SA Category-I and SA Category-II ILSs. Civil and state aircraft equipage and operational needs will also be considered in the rationalization process.

The ILS Rationalization Initiative has established initial criteria to identify which systems could be retained to meet operational requirements and which can be discontinued to reduce recurring operating costs.

6.0 Global Navigation Satellite System (GNSS) Programs

Figure 18: GPS Satellite

For aviation use in the United States, GNSS consists of GPS satellites augmented by Aircraft Bases Augmentation System (ABAS), Satellite- Based Augmentation System (SBAS), and Ground Based Augmentation System (GBAS). ABAS uses Receiver Autonomous Integrity Monitoring (RAIM) in the aircraft avionics to enable use of GPS for two-dimensional navigation. The FAA's implementation of SBAS is the Wide Area Augmentation System (WAAS), which improves the accuracy, integrity, and availability of GPS for all phases of flight to include vertically guided approach. GBAS is intended to improve the accuracy and integrity of GPS to support Category-III precision approach operations. Other international ANSPs plan to use SBAS; for example, the Russian Federation operates the GLONASS constellation and its SBAS, referred to as System of Differential Correction Monitoring (SDCM). The European Union (EU) is building the Galileo constellation. The current EU SBAS referred to as European GNSS Overlay System (EGNOS) augments GPS, with plans to augment Galileo in the future; and China is building the BeiDou constellation and building its own SBAS. Japan and India are also operating their own SBAS: MTSAT Satellite Augmentation System (MSAS) and GEO and GPS Augmented Navigation (GAGAN), respectively. Korea, Africa, and in Australia are exploring the potential for SBAS systems. RTCA and European Organization for Civil Aviation Equipment (EUROCAE) organizations develop avionics standards for GNSS and have work plans to develop Dual Frequency Multiple Constellation SBAS Minimum Operational Performance Standards (MOPS) by 2022-2023. The use of additional core constellations from other international ANSPs can improve the availability of GNSS-based navigation in the NAS, which may eventually lead to further rationalization of conventional and satellite-based navigation systems by FAA beyond the Far-Term. ADS-B also depends on GPS and WAAS to achieve its most stringent performance levels.

6.1 Global Positioning System (GPS)

The GPS, shown in **Figure 18**, consists of a nominal constellation of 24 Medium Earth Orbit (MEO) satellites orbiting in six 11,000-mile orbits inclined at 55 degrees to provide precise positioning and timing service for world-wide civil use with no direct service charges.

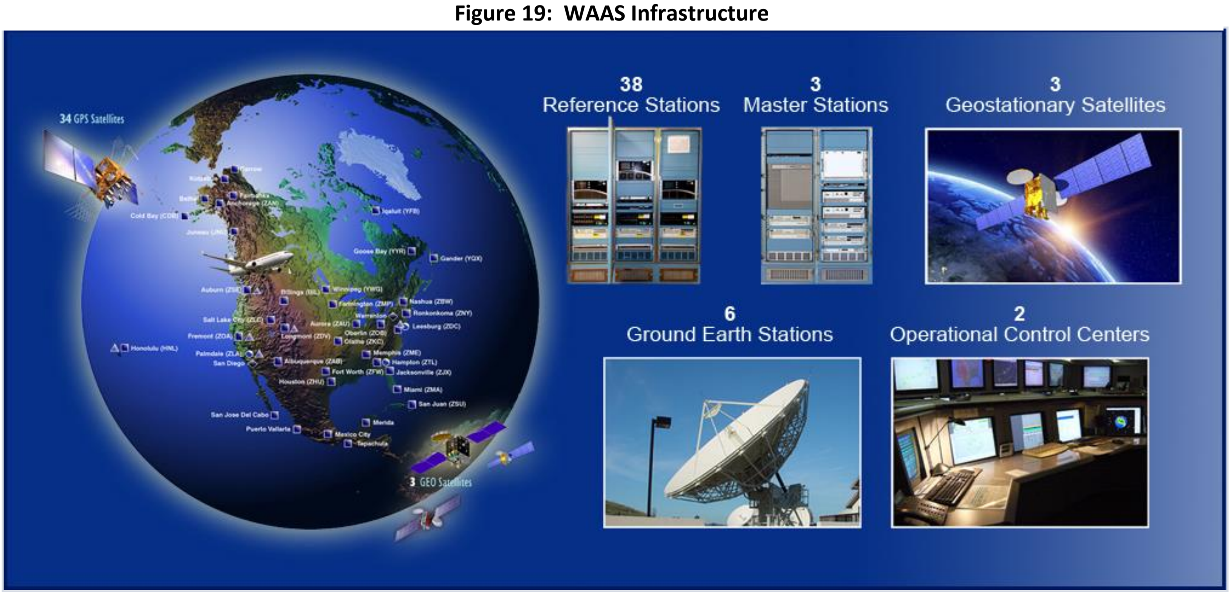
GPS alone cannot meet all aviation requirements, or support vertically guided precision approaches. GPS with RAIM may experience periods of unavailability that limit where and when an aircraft can fly PBN procedures. Because of these limitations, GPS with RAIM is authorized only for supplemental use, meaning the aircraft must carry other navigation systems for primary use. In order to use GPS as the primary means of navigation, and to fly vertically guided approaches, GPS must be augmented with either SBAS or GBAS.

Because GPS signals are very low power, below the ambient noise level, they are vulnerable to disruptions caused by RFI and Hazardously Misleading Information (HMI) caused by spoofing. Therefore, the navigation strategy will retain and repurpose a minimum operational network of VORs and the NextGen DME Program will improve DME coverage to provide a resilient navigation infrastructure to ensure safe operations in the event of a GPS outage.

6.2 Wide Area Augmentation System (WAAS)

WAAS consists of a wide area network comprising 38 monitoring stations that collect GPS signals, which are sent to three master stations which compute and generate corrections and integrity messages. WAAS then uplinks these messages from six earth stations to three GEO satellites for broadcast to user aircraft, shown in **Figure 19**. Aircraft can use both GPS and WAAS to obtain the precise navigation service at more than 5,000 qualifying runways ends (which is used to fly vertically guided approaches) equivalent to ILS Category-I. WAAS covers all of CONUS and large portions of Alaska, Mexico, and Canada. WAAS is monitored and controlled from two operations consoles located on the east and west coasts of CONUS.

Figure 19: WAAS Infrastructure



6.2.1 WAAS Program

The WAAS Program consists of four phases, three of which have been completed (see **Table 5**). Each phase of the program is designed to provide additional levels of operational capability that build upon the performance of previous phases. These additional capabilities satisfy increasing user demand and the FAA's goal of increased safety, capacity, and international leadership as the first ANSP to implement SBAS technology. As GPS is modernized by the US Air Force (USAF), the

FAA must modify WAAS to continue providing service to the aviation community. The USAF is adding a new GPS signal (L5) and restricting civil use of the GPS signal L2, which requires changes to the WAAS ground system. The L5 signal will provide improved accuracy and availability, particularly during ionosphere disturbances, to aviation users who equip with dual-frequency avionics. During Phase IV, WAAS will implement the Dual-Frequency Operations (DFO) to provide ubiquitous LPV-200 capability across the NAS. DFO requires infrastructure improvements to provide new correction and integrity messages broadcast from the WAAS GEOs, as well as new dual-frequency avionics standards.

Table 5: The Four Phases of WAAS

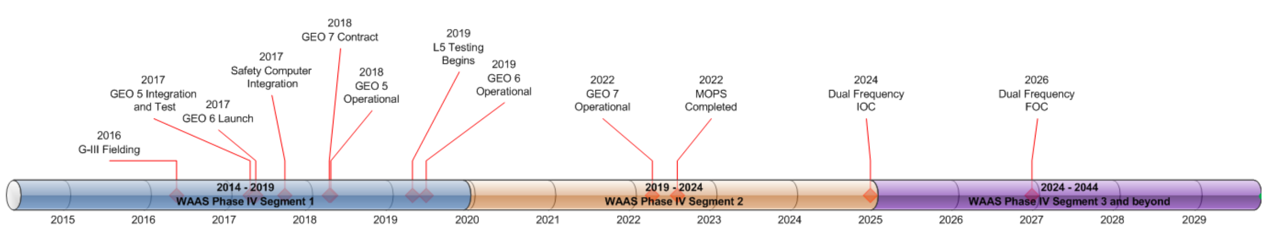
Phase	Operational Capability Goal	Status
Phase I	Initial Operating Capability (IOC)	Completion achieved in 2003
Phase II	Full LPV Performance (FLP) with 250-foot minimums	Completion achieved in 2008
Phase III	Full FLP with 200-foot minimums (LPV-200)	Completion achieved in 2013
Phase IV	Dual-Frequency Operations (DFO)	Ongoing (2014–2044)

DFO will be implemented as a series of incremental changes while backward compatibility is maintained for current single-frequency users.

6.2.2 WAAS Strategy

As WAAS strategy, shown in **Figure 20**, evolves into DFO, a critical aspect of Phase IV includes the continued provision of the existing single-frequency service which includes sustainment of the existing three GEO satellite constellations. The WAAS Program is currently investigating the use of Dual Frequency Multi-Constellation (DFMC) as an extension of the planned Dual-Frequency capability. The WAAS Program is also working to develop an Advanced RAIM (ARAIM) capability. ARAIM has the potential to provide an ABAS-based precision approach capability. Vertical ARAIM capability, when deployed by a sufficient number of users, could significantly reduce the need for a GEO broadcast capability. Realization of a full vertical ARAIM performance capability would not likely be available until well after the Far-Term in 2044.

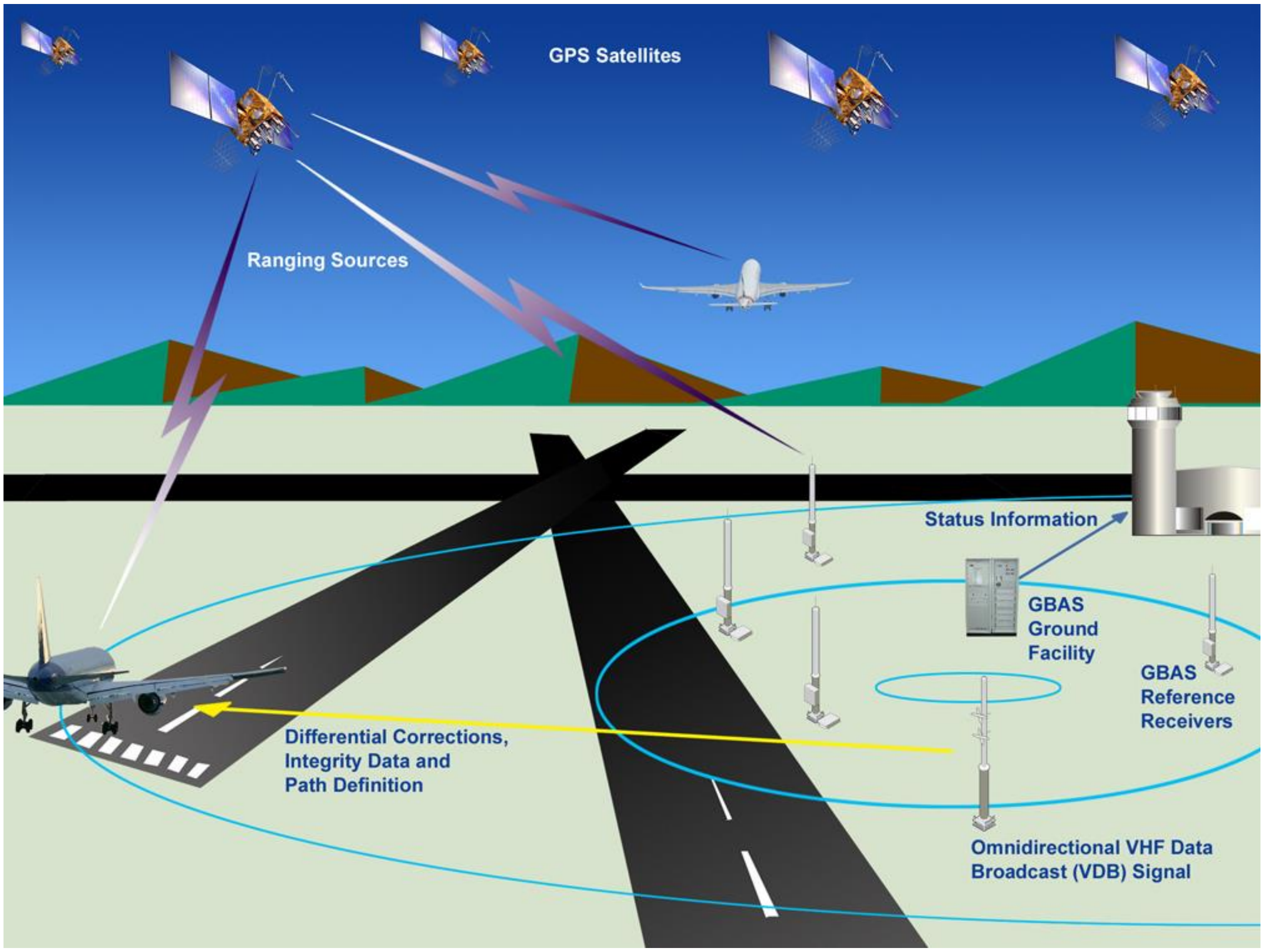
Figure 20: WAAS Strategy



6.3 Ground Based Augmentation System (GBAS)

The GBAS, shown in **Figure 21**, in a non-fed system in the NAS which augments GPS to provide an all-weather approach and landing capability. GBAS is an ICAO-compliant system that provides final approach guidance for Category-I precision approach and landing services by broadcasting differential GPS corrections, integrity information, and approach/departure path information via a VHF data link. In 2009, the FAA completed regulatory approval of the Honeywell SLS-4000, Category-I system as a non-Federal system. An FAA cost-benefit analysis for the GBAS is currently underway for a Category II/III capability in the NAS.

Figure 21: Ground Based Augmentation System (GBAS)



Since the initial 2009 Category-I System design approval of the Honeywell SLS-4000, two updates have been approved. The first update was performed to improve the reliability of the GBAS in RFI-challenged environments associated with personal privacy devices at the Liberty International Airport (EWR) in Newark, New Jersey. The second update included improvements to increase overall availability, the addition of an optional WAAS receiver to decrease overbounding of the ionospheric error, and modifications to make the system more easily tailored for implementation in iono-rich low-latitude environments.

Public Category-I SLS-4000 systems are fully operational at EWR and George Bush Intercontinental (IAH) airports. As of March 2017, more than 3,900 approaches have been conducted using these two systems. Users included domestic airlines (United Airlines and Delta Airlines) and foreign carriers such as Lufthansa, Cathay Pacific, Emirates, CargoLux and British Airways. In addition, the Boeing Company has installed two private SLS-4000s at Moses Lake, Washington (MWH) and Charleston (CHS) for use in aircraft acceptance flights.

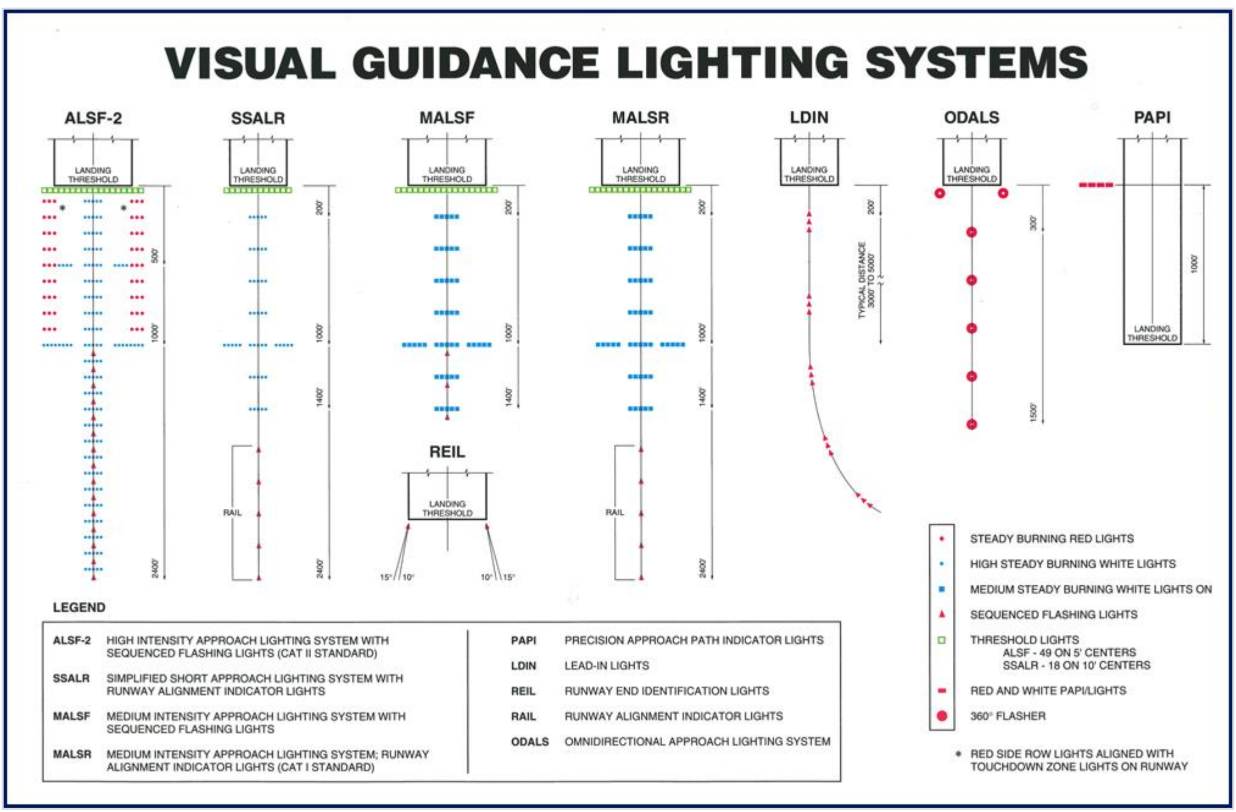
7.0 Visual Guidance Lighting Systems (VGLS) Strategy

The FAA operates NavAids that provide visual guidance to pilots during the approach and landing phases of flight. These NavAids include Approach Lighting Systems (ALS), Visual Approach Slope Indicators (VASI), Precision Approach Path Indicators (PAPI), Runway End Identifier Lights (REIL), Omni-directional Approach Lighting Systems (ODALS), and Lead-in Lights (LDIN). Collectively, these NavAids are referred to as VGLS, which enable pilots to more effectively:

- Identify the runway environment
- Align with the runway centerline
- Achieve a stable, wings-level attitude for landing

There are many existing variants and configurations of ALS including the Medium Intensity Approach Lighting Systems (MALS); MALS with Runway Alignment Indicator Lights (MALSR); Simplified Short Approach Lighting System (SSALS); and SSALS with Sequenced Flashers (SSALR), ODALS, and High-Intensity Approach Lighting Systems with Sequenced Flashing Lights (ALSF-2), as depicted in **Figure 22**. Each ALS is designed to support the approach and landing phase of flight and to meet the specific needs of each runway and varying terrain conditions.

Figure 22: Existing Configurations of Approach Lighting Systems (ALS)



Navigation Programs Strategy

7.1 Precision Approach Path Indicator (PAPI)

The PAPI system is the current standard Visual Glide Slope Indictor (VGSI) that projects a pattern of red and white lights that provide visual approach slope information. The system provides a definite white and red light projection pattern along the desired descent path to the touchdown point, shown in **Figure 23**. PAPIs and VASIs are designed to reduce CFIT and landing distance over and under runs by assisting the pilot in establishing a stabilized descent. The VASI consists of a set of four lights located either on one side of a runway or straddling a runway.

Figure 23: PAPI Lights

There are currently 633 VASIs in the NAS, all of which are beyond their 20-year service life. There are approximately 1,158 PAPI systems in the NAS, approximately 52% of which are being operated beyond their 20-year service life. In 2016, the FAA received an In-Service Decision to begin fielding the FA-30200 LED PAPI. Under the current procurement contract, the FAA has the option to acquire up to 500 LED PAPI systems. The benefits of new LED technology include requiring less energy to create the same light output and extending the life of the PAPI lamps from 2,000 hours to at least 40,000 hours.

7.1.1 PAPI Replace VASI Program

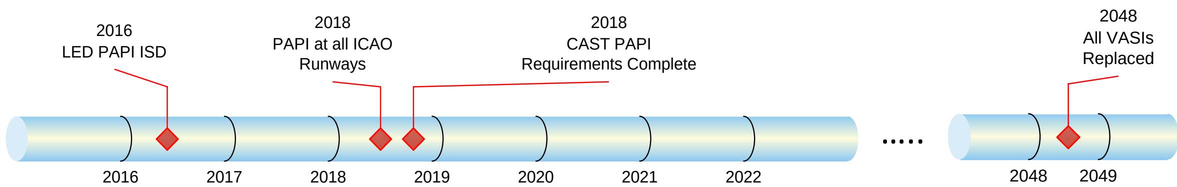
ICAO has recommended that all international airports replace the VASI with PAPI systems to standardize the VGSI equipment used by pilots. The program supports the procurement, installation, and commissioning of PAPI systems in order to comply with the ICAO recommendation. The first priority of the PAPI Replace VASI Program is to replace VASI systems at approximately 329 ICAO-designated runway ends. As illustrated in **Figure 24**, these replacements are estimated to be completed in 2018.

7.1.2 PAPI Establish Program

PAPI systems are established to meet requirements for new qualifying runways. CAST recommended that the FAA implement VGSI approach capability on various airport runways including those affected by Land and Hold Short Operations (LAHSO) requirements. The CAST includes representatives from FAA, airlines, and airport personnel. CAST identified 781 runway ends requiring implementation of a VGSI approach capability to reduce the number of the CFIT accidents that occur during approach and landing. The CAST PAPI requirement will be completed by 2018.

LAHSO is an air traffic control tool used to increase airport capacity by allowing coordinated approaches on intersecting runways. Vertical guidance is required for air carrier operations on the short runway hold in order to avoid landing long and conflicting with operations on other runways.

Figure 24: PAPI Schedule



7.2 MALSR

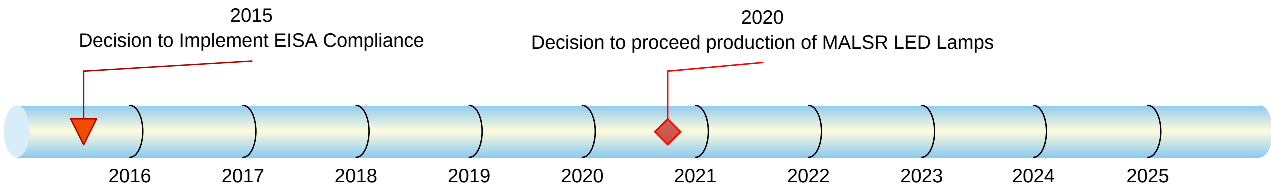
Figure 25: Medium Intensity ALS with Runway Alignment (MALSR)

A MALSR, shown in **Figure 25**, is a medium-intensity ALS installed in airport runway approach zones along the extended centerline of the runway. MALSRs consist of a combination of steady burning light bars and flashers that provide to pilots visual information on runway alignment, height perception, roll guidance, and horizontal references to support a visual landing following an ILS approach. MALSRs currently use PAR 38 and PAR 56 incandescent lamps adjustable to three levels of intensity. Medium ALS with Sequenced Flasher (MALSF) and Medium ALS (MALS) are configuration variants of the MALSR that are used at locations where terrain or real estate considerations cannot support a full MALSR system. By extending the visual runway environment by 2,400 feet (approximately ½-mile) up the approach path, a MALSR allows pilots to continue an approach when visibility is ½-mile (rather than ¾-mile).

7.2.1 MALSR Establish and Sustainment Programs

The MALSR program schedule is provided in **Figure 26**. There are approximately 884 MALSR, MALSF, and MALS systems in the NAS. Approximately 73% of the MALSRs and their associated sub-systems are operating beyond their 20-year service life. The FAA's current procurement contract for MALSR systems ends in 2017. The FAA will continue to sustain MALSR systems to support Category-I and SA Category-II approach service. Priority for sustainment is given to the oldest MALSR systems or the systems with the least reliable performance. The FAA encourages cost-saving opportunities when a MALSR system can be installed during an airport-financed project. The FAA establishes MALSR systems at qualifying runways in support of Category-I approaches or to obtain a 1/4-mile visibility credit. At many locations, the ¼-mile credit provided by MALSR makes a significant difference in the ability of aircraft to land at their primary destinations rather than the pilot having to execute a missed approach, attempt additional approaches, or divert to an alternate airport.

Figure 26: MALSR Program Schedule



7.3 ALSF-2

Figure 27: ALSF-2

An ALSF-2, as shown in **Figure 27**, is required to support all Category-II/III ILS approaches. An ALSF-2 consists of a lighting field significantly larger than a MALSR, uses larger PAR 56 red and white incandescent lamps, and is capable of five levels of intensity. It also incorporates sequenced flashers, a green threshold bar, and landing zone lights. There are approximately 153 ALSF-2 systems in the NAS. Presently, about 51% of the ALSF-2 systems operate beyond their 20-year service life.

7.3.1 ALSF-2 Establish and Sustainment Program

The FAA establishes ASLF-2 systems at qualifying runways in support of Category-II/III approaches. The FAA sustains old ALSF-2 systems at selected sites via the Replacement Lamp Monitoring System (RLMS) project. The RLMS is a service life extension project for ALSF-2 that replaces oil-type constant current regulators (CCR) with environmentally friendly dry-type CCRs and installs an improved and highly reliable lamp monitoring system. The RLMS has successfully increased old ALSF-2 systems' adjusted operational availability from 98.4 to 98.7. There are no plans to procure full ALSF-2 systems at this time.

7.4 Runway End Identifier Lights (REIL)

Figure 28: REIL Lamp Enclosure

The REIL system, as shown in **Figure 28,** provides rapid and positive identification of the end of runways. The system consists of two synchronized, unidirectional flashing lights that are positioned on each corner of the runway landing threshold, facing the approach area and aimed at an angle of 10 to 15 degrees. The REIL is effective for identifying a runway surrounded by a preponderance of other lighting; identifying a runway that lacks contrast with surrounding terrain; and identifying a runway during reduced visibility. The REIL system provides three intensity settings and has an approximate range of three miles in daylight and twenty miles at night. A REIL system can be controlled from the air traffic control tower, remotely by the pilot, or manually from the control cabinet. **Figure 28** shows one of the two lamp enclosures comprising a REIL system installed next to the runway threshold. There are approximately 718 REIL systems in the NAS, approximately 53% of which are beyond their 20-year service life. Navigation Programs is developing a LED REIL specification which will leverage of LED technology,' lower operating costs, and improved reliability.

7.4.1 REIL Sustainment Program

The FAA has a procurement contract for the FA-19900 REIL. The FAA received delivery of approximately 250 REIL systems under this contract and is currently sustaining REILs at select airports. Priority for sustainment is given to the oldest systems or the systems with the least reliable performance.

7.5 Omni-Directional Approach Lighting System (ODALS)

ODALS is a configuration of seven omni-directional sequenced flashing lights located near the runway threshold. The ODALS provide circling, offset, and straight-in visual guidance for non-precision approach runways. There are approximately 27 ODALS in the NAS, all of which are being operated beyond their 20-year service life. There are no plans to procure or replace ODALS systems at this time because so few are needed; they are maintained organically by the FAA Logistics Center.

7.6 Lead-in Lights (LDIN)

LDINs are uniquely designed sequenced flashing lights that are installed beyond runway ends to provide pilots flying a visual approach with visual guidance toward a runway where an extended straight-in approach is not possible or would impact airspace efficiency. There are 13 LDIN systems currently in use, 12 of which are operating beyond their 20-year service life. The FAA will sustain LDIN systems depending on operational need on a case by case basis.

7.7 Runway Visual Range (RVR)

Figure 29: Runway Visual Range (RVR)

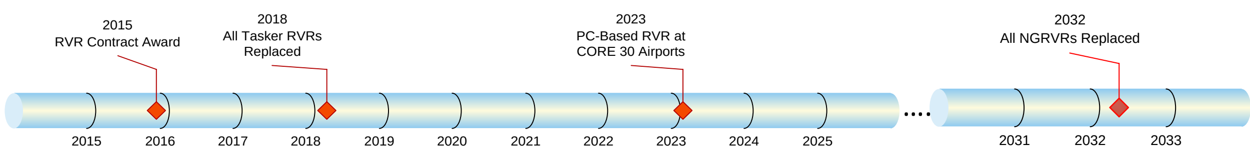
RVR equipment, shown in **Figure 29**, is located next to a runway that provides air traffic controllers with a measurement of the visibility at key points along a runway (e.g., touchdown, midpoint, and rollout). These data are used to decide whether it is safe to take off or land during limited visibility conditions. During reduced visibility weather conditions, RVR system measurements are used by air traffic controllers to establish airport operating categories. The RVR reading is key to determining the category of precision approach capability required to conduct safe aircraft operations. Visibility conditions down to RVR 2400 (2,400 feet of visibility) are supported by Category-I instrument approach procedures. Using on-board enhanced vision equipment, visibility conditions are reduced to an RVR of 1800 feet. Visibility conditions down to RVR 1000 are supported by Category-II ILS instrument approach procedures.

Visibility conditions of RVR 700, RVR 600, and RVR 300 are supported by Category-III ILS instrument approach procedures, depending on avionics, flight crew qualifications, and other airport regulatory and equipment requirements.

7.7.1 RVR Sustain Program

The FAA operates and maintains more than 300 RVR systems in the NAS, approximately 89% of which are beyond their 20-year service life. Through the use of modern commercial products and components, the Personal Computer (PC)-based RVR exceeds reliability, maintainability, and availability of all previous RVR systems. The PC-based RVR will replace all the transmissometers and address component obsolescence issues with the New Generation (NG) RVR in the NAS. RVR systems are being procured to support new precision approaches; Enhanced Low Visibility Operations (ELVO), described in Section 8.1; and the sustainment of existing facilities. **Figure 30** illustrates the RVR Sustain Program schedule.

Figure 30: RVR Program Schedule



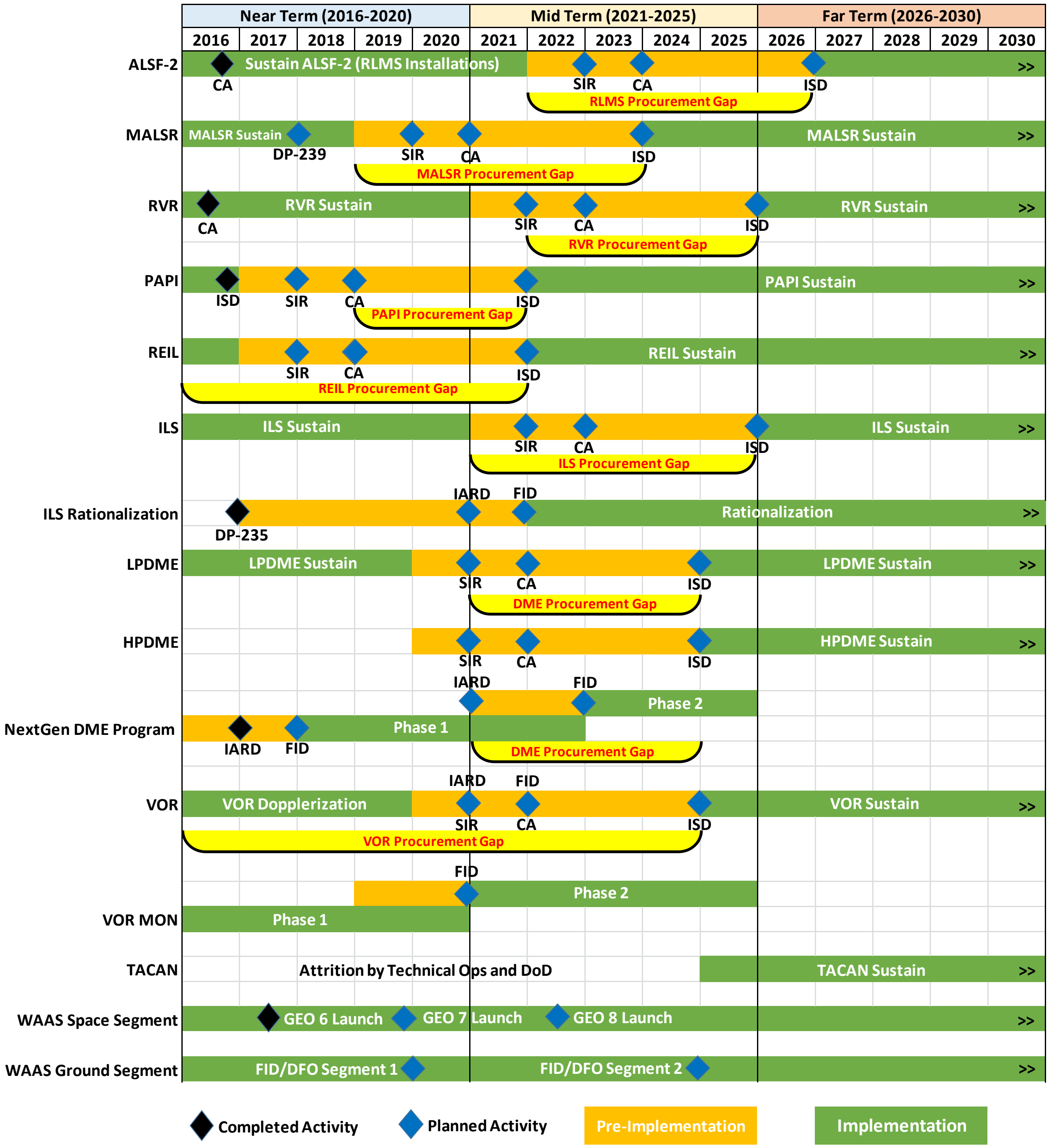
8.0 Sustainment and Program Summary

The Navigation Programs Strategy describes the systems and programs included in the Navigation Infrastructure Roadmap from the NAS Enterprise Architecture[5] (NAS EA), which comprise the Navigation Portfolio. **Figure 31** depicts the acquisition management view of the Navigation Portfolio. Planned Screening Information Request (SIR) releases, Contract Awards (CA), and FAA Acquisition Management System (AMS) milestones are depicted along with any projected procurement gaps.

[5] See section 16.0 Appendix D – NextGen OIs dependent on Navigation

Navigation Programs Strategy

Figure 31: Sustainment and Program Strategy Chart



9.0 Other Navigation Programs

9.1 Enhanced Low Visibility Operations (ELVO) Program

The FAA has increased commercial aircraft access to a vast number of airports during very low-visibility conditions through a program known as ELVO. The ELVO Program has two phases: Phase I–RVR 1800 and Phase II–SA Category-I.

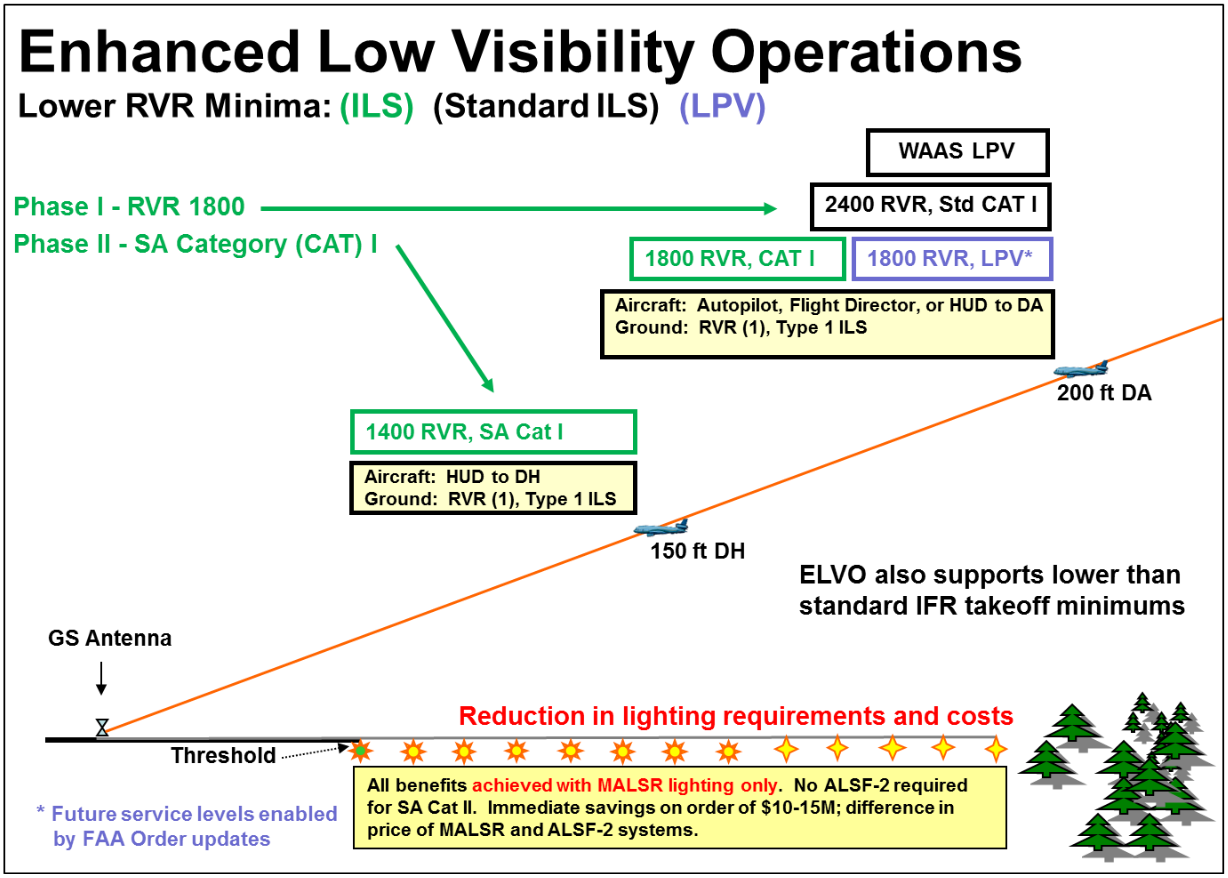
ELVO Phase I established the criteria for low-visibility operations and implemented more than 900 new procedures that did not require infrastructure investment. This phase reduced the landing visibility requirement from 2,400 to 1,800 feet for Category-I ILS approaches. Minimums required for landing and takeoff use measurement data from RVR systems. By lowering the RVR-defined minimums for arrivals and departures, additional flight operations can occur and increase NAS capacity by decreasing delays and diverts for flight operations.

ELVO Phase II is described in more detail in the next subsection. Phase II combines changes to procedures, with modest investments in ILS improvements and additional RVR sensors, to reduce the landing visibility requirement from 2,400 to 1,400 feet with SA Category-I (as shown in **Figure 32**). The DA is also reduced, from 200 to 150 feet. Modest investments in additional infrastructure permit SA Category-II operations at runways without ALSF-2 approach lighting and/or runway touchdown zone/center line lights. This ILS and RVR infrastructure can reduce minimums to as low as 1,200 RVR and to a DA 100 feet. For example, additional RVR sensors have reduced the RVR required for departures from 1,600 RVR down to as low as 500 feet.

9.1.1 ELVO Phase II Program

ELVO Phase II is the active phase of the program within Navigation Programs. It’s required to demonstrate the value of low-visibility procedures and determine the benefit to the NAS at additional sites that needed investment to bring the runway ends up to compliance. To achieve this end, a cost model was developed for ELVO Phase II, which the Joint Resources Council (JRC) approved as a baselined program in December 2012. The Phase II program is tasked with implementing newer services (1,800 RVR, SA Category-I, SA Category-II, and/or lower than standard IFR takeoff minimums) at 15 or more sites. The first three sites, Westchester/White Plains (HPN), Islip (ISP), and San Jose (SJC), are completed. The remaining 12 will be completed by 2018. In addition, the program is targeting 11 more sites by 2020.

Figure 32: ELVO Lower RVR Minima



9.2 Runway Safety Area (RSA)

The FAA's runway safety program includes numerous programmatic elements intended to improve the overall safety of the runway environment and Runway Safety Areas (RSA). As illustrated in **Figure 33**, the standard dimension of an RSA is 250 feet on either side of the runway center line and 1,000 feet extending beyond the runway thresholds. The RSA must be free of all not-frangible objects that are 3 inches above grade. The Air Traffic Organization (ATO) agreed to correct approximately 570 RSAs of varying size and complexity that need to be addressed at multiple airport locations by the end of Calendar Year 2018. These projects replace, relocate, and/or correct non-compliant—at an average rate of 82 RSAs per year–FAA-owned equipment that lies within the RSAs.

Figure 33: Standard Runway Safety Area Dimensions

10.0 Innovations

The following programs and initiatives are unique in the way that Navigation Programs executes its programs. All the programs listed in this section are vital to the future state of Navigation Programs and support the FAA's mission to continuously improve the NAS.

Section 10.1 describes ARAIM, a unique collaboration among multiple FAA offices, ICAO, and RTCA that aims to begin using satellites from multiple core constellations in order to enable global vertical approach operations.

Section 10.2 describes APNT, a future navigation service that will provide resiliency in the event of a GPS disruption. APNT is being designed to improve upon the services delivered by the NextGen DME Program.

Section 10.3 describes GBAS, a collaboration between multiple FAA offices that works toward augmenting GPS to provide an all-weather approach and landing capability.

Section 10.4 describes lighting initiatives that are currently in the research and development (R&D) phase. These are projects within Navigation Programs that explore ways to expand the use of LED technology to more VGLS.

10.1 Advanced Receiver Autonomous Integrity Monitoring (ARAIM)

The ARAIM concept provides a means to use multiple frequencies and multiple constellations to enable global vertical approach operations. ARAIM represents a replacement technology for the current RAIM algorithm that augments only GPS and supports only non-precision approach lateral guidance. Through the use of multiple constellations, ARAIM is capable of achieving sufficient availability with core constellations that are weaker than the 31 satellite GPS constellation currently available.

To achieve vertical guidance, ARAIM will need to provide a deeper level of safety assurance than the first generation of RAIM used for lateral navigation. This is necessary because vertical guidance is associated with a severe-major hazard level. To include ARAIM in the DFMC SBAS avionics being developed to support dual-frequency users, the ARAIM concept has been split into a Horizontal ARAIM (H-ARAIM) concept (intended for earlier adoption) and a Vertical ARAIM (V-ARAIM) concept that requires additional development to reach full maturation.

ARAIM requires integrity inputs on relative constellation performance. Unlike RAIM, the ARAIM includes a method to update or change these integrity inputs. Because the integrity inputs can be conservative and still provide good availability for horizontal navigation, it is possible to proceed with H-ARAIM in the near-term. The concepts for developing the integrity inputs supporting V-ARAIM require additional research to develop and demonstrate; therefore, the decision to implement V-ARAIM is being delayed.

Current FAA activities support ARAIM concept development jointly with the European Union (EU). There is an ARAIM technical sub-group (TSG) to the EU-US GPS-Galileo bilateral collaboration. The ARAIM TSG is finalizing a Milestone III report that defines the current ARAIM concept. The FAA will continue to develop the ARAIM concept, including the ground monitoring portion that develops and validates the required integrity parameters. Additionally, the FAA will continue to support inclusion of ARAIM in dual-frequency MOPS at RTCA. The effort would benefit from ARAIM prototype efforts, although none are planned at this time.

10.2 Alternate Positioning, Navigation, & Timing (APNT)

The FAA published the *PBN NAS Navigation Strategy 2016* that identifies resiliency initiatives in the near-term (2015–2020, mid-term (2021–2025), and far-term (2026–2030). In the near- and mid-term, the FAA defined the operational environment for resiliency in the terminal domain as RNAV 1 and in the en-route domain as RNAV 2. Based on the aforementioned requirements, resiliency can be met by the NextGen DME Program. As a result, APNT was defined in the *PBN NAS Navigation Strategy 2016* as a far-term effort and moved to NextGen Research.

10.3 Ground Based Augmentation System (GBAS)

GBAS has accomplished safe Category-I approach service as described in section 6.3 and system improvements and innovations are progressing. Requirements validation for GBAS Approach Service Type D (GAST-D), which is an ICAO Standards and Recommended Practices (SARPS) initiative, was completed in December 2016 and standards will take effect in 2018. GAST-D will extend GBAS service to Category-III minima. The FAA NextGen Program has supported a cooperative effort with Honeywell International to build a commercial prototype GAST-D ground system and associated avionics. These prototypes have been used as a test bed for the requirements validation activity, and results have been presented at RTCA Inc., ICAO, and the International GBAS Working Group (IGWG) over the past six years. The IGWG is a group of ANSPs, ground, avionics, and aircraft manufacturers and users interested in implementing GBAS. Many of the IGWG members have participated in and supported the requirements validation activities through weekly ICAO/RTCA teleconferences that are supported by the FAA GBAS team, its support contractors and university key technical advisors.

Honeywell International is pursuing System Design Approval (SDA) for its GAST-D/Category-III-capable system (the SLS-5000). The FAA will conduct reviews of vendor SDA safety documentation through calendar year 2017.

10.4 Lighting Initiatives

In 2001, the FAA VGLS Team initiated an effort to replace incandescent lamps with more efficient lamps. The FAA researched various types of lighting technologies and concluded that LED lamps are the most practicable to implement.

To encourage energy-efficient lighting, the President of the United States signed the 2007 Energy Independence and Security Act mandating that incandescent lamps of certain wattages no longer be produced and that manufacturers of incandescent airport lighting systems comply by changing to LED technology. To conform to the 2007 Energy Independence and Security Act, the FAA Lighting Systems Team has awarded contracts to procure PAR-38 and PAR-56 LED lamps, which are used in the MALSR systems. These lamps have been installed at test sites around the country, and the FAA is in the final evaluation stages to implement LED lamps safely into the NAS without negative affects to pilots and airspace users.

Some ALS systems require approximately 200 lamps and extend 2,400 feet from the runway threshold. There may be future opportunities to shorten that length and/or reduce the amount of lamps included in each system. For example, with the assistance of Head-Up Display (HUD) and Enhanced Vision System (EVS), future initiatives may reduce the physical footprint of ALS.

11.0 Summary

This Navigation Programs Strategy detailed the FAA’s plan to provide safe and cost-effective navigation capabilities to meet the operational needs of the NAS; today and in the future. It described the sustainment plans of current Navigation systems and the implementation of innovative capabilities such as ARAIM and DFMC. This Navigation Strategy supports the evolution of PBN as the preferred means of navigation by sustaining and expanding the use of GNSS, providing a PBN-capable backup with the DME, and a minimum operational network of VORs to ensure aircraft can navigate safely during GNSS outages. As part of the resilient solution, the legacy Ground-Based Navaids will be maintained for the foreseeable future. However, the transition to PBN provides an opportunity to rationalize the inventory of NavAids while sustaining those required for the resilient navigation infrastructure. Navigation Programs will develop an effective and cost-efficient sustainment strategy for long term supportability of the legacy NavAids and Lighting Systems. Navigation Programs is dedicated to improving the NAS by determining the optimal balance of GNSS and legacy systems.

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13.0 Appendix A – Glossary

Accuracy – the degree of conformance between the estimated, measured, or desired position; or the velocity of a platform at a given time and its true position or velocity; presented as a statistical measure of system error.

Availability – the ability of a system to provide the required function and performance at the initiation of the intended operation.

Backup –an alternative means of positioning and/or navigation; may have performance that is not as efficient as the principal means of positioning and/or navigation.

Containment Continuity – as it applies to RNAV/RNP, the capability of the total system to satisfy the containment integrity requirement without nonscheduled interruptions during the intended operation; specified by the maximum allowable probability for interruption.

Continuity – the capability of the total system (comprising all elements necessary to maintain a user's position within the defined space) to perform its function without nonscheduled interruptions during the intended operation.

Coverage – the geographic area where the application-specific radionavigation system requirements for accuracy, availability, integrity, and continuity parameters are satisfied at the same time.

Critical DME – A DME facility that, when unavailable, results in navigation service that is insufficient for DME/DME/IRU-supported operations along a specific route or procedure.

Decommission – the elimination of the physical site and associated environmental clean-up, surplus of the property; also involves discontinuance of maintenance support.[6]

Discontinuance – a decision to cease providing the navigational signal from the navigational aid.

Integrity – the ability of a system to provide timely warnings to users when the system should not be used.

New Establishment – a navigational aid that has not previously been implemented and represents an expansion of service to a new location.

Redundant – an alternative means of positioning and/or navigation that duplicates the performance of the principal means of positioning and/or navigation.

[6] One physical navigational facility may support multiple navigation and communications functions. A VOR may be discontinued but the site continues to support DME or air-ground voice communications. In this case, the VOR is discontinued, but the site is not decommissioned.

Replacement – a method of sustainment through which the existing navigational aid is beyond useful life and cannot be sustained with a service-life extension, and is replaced (recapitalized) with a new unit.

RNAV – a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

RNAV 1 – requires a total system error of not more than 1 NM for 95% of the total flight time.

RNAV 2 – requires a total system error of not more than 2 NM for 95% of the total flight time.

Service-Life Extension – a method of sustainment that extends the life of a navigational aid through the upgrade of elements of the navigation system.

Sustain – the process of continuing, for an extended period, the delivery of navigation services.

14.0 Appendix B – Acronyms

Acronym	Definition
ABAS	Aircraft Based Augmentation Systems
ADS-B	Automated Dependent Surveillance-Broadcast
AGL	Above Ground Level
ALS	Approach Lighting System
ALSF-2	High Intensity Approach Lighting System with Sequenced Flashers
AMS	Acquisition Management System (AMS)
ANSP	Air Navigation Service Provider
APNT	Alternative Position, Navigation and Timing
AR	Authorization Required
ARAIM	Advanced Receiver Autonomous Integrity Monitoring
ATO	Air Traffic Organization
CA	Contract Award
CAST	Commercial Aviation Safety Team
CCO	Continuous Climb Operations
CCR	Constant Current Regulators
CDO	Continuous Descent Operations
CFIT	Controlled-Flight-into-Terrain
CONUS	Continental United States
DA	Decision Altitude
DF	Direction Finder
DFMC	Dual Frequency Multi-Constellation
DFO	Dual-Frequency Operations
DME	Distance Measuring Equipment
DoD	Department of Defense
DVOR	Doppler VOR
EA	Enterprise Architecture
EFVS	Enhanced Flight Vision System
EGNOS	European GNSS Overlay System
ELVO	Enhanced Low Visibility Operations
ESL	Economic Service Life
EU	European Union
EVS	Enhanced Vision System
FAA	Federal Aviation Administration
FID	Final Investment Decision
FL	Flight Level
FMS	Flight Management System
FTE	Flight Technical Error
GANP	Global Air Navigation Plan

Acronym	Definition
GAST-D	GBAS Approach Service Type D
GBAS	Ground-Based Augmentation System
GBNA	Ground-Based Navigation Aids
GEO	Geostationary
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GS	Glide Slope
H-ARAIM	Horizontal ARAIM
HAA	Height Above Airport
HMI	Hazardously Misleading Information
HPDME	High-Power DME
HUD	Head-Up Display
IARD	Investment Analysis Readiness Decision
ICAO	International Civil Aviation Organization
ICMS	Integrated Control and Monitoring System
IFP	Instrument Flight Procedure
IFR	Instrument Flight Rules
IGWG	International GBAS Working Group
IID	Initial Investment Decision
IOC	Initial Operational Capability
ILS	Instrument Landing System
IM	Inner Marker
IMC	Instrument Meteorological Conditions
IRU	Inertial Reference Unit
ISR	In-Service Decision
JRC	Joint Resources Council
LAHSO	Land and Hold Short Operations
LDIN	Lead-In Lighting System
LED	Light Emitting Diode
LNAV	Lateral Navigation
LOC	Localizer
LMM	Locator Middle Marker
LP	Localizer Performance
LPDME	Low-Power DME
LPV	Localizer Performance with Vertical guidance
MALS	Medium Intensity Approach Lighting System
MALSF	Medium Intensity Approach Lighting System with Sequenced Flashing Lights
MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights
MEO	Medium Earth Orbit
MHz	Megahertz
MM	Middle Marker

Acronym	Definition
MON	Minimum Operational Network
MOPS	Minimum Operational Performance Standard
MSL	Mean Sea Level
NAS	National Airspace System
NAVAID	Navigational Aid
NDB	Non-directional Beacon
NESS	NAS Efficient Streamlined Services
NextGen	Next Generation Air Transportation System
NGIP	NextGen Implementation Plan
NSG	Navigation Service Group
ODALS	Omni-directional Approach Lighting System
OI	Operational Improvement
OM	Outer Marker
OTW	Out-the-window
PAPI	Precision Approach Path Indicator
PBN	Performance Based Navigation
PBNRS	Performance Based Navigation Route Structure
PNT	Position, Navigation and Time
Q-Route	High altitude RNAV published ATS routes
RAIM	Receiver Autonomous Integrity Monitoring
REIL	Runway End Identifier Lights
RFI	Radio Frequency Interference
RLMS	Replacement Lamp Monitoring System
RNAV	Area Navigation
RNP	Required Navigation Performance
RTCA	RTCA Inc. (formerly Radio Technical Commission for Aeronautics)
RVR	Runway Visual Range
SA	Special Authorization
SATNAV	Satellite Navigation
SARPS	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SDA	System Design Approval
SID	Standard Instrument Departure
SIR	Screening Information Request
SMGCS	Surface Movement Guidance and Control System
SOCC	Satellite Operations Coordination Concept
SDCM	System of Differential Correction Monitoring
SPS	Standard Positioning Service
SSALR	Simplified Short Approach Lighting System with Runway Alignment Indicator Lights
SSALS	Simplified Short Approach Lighting System
SSV	Standard Service Volume

Acronym	Definition
SV	Service Volume
STAR	Standard Terminal Arrival
T-Route	Low altitude RNAV ATS Routes
TACAN	Tactical Air Navigation
TACR	TACAN at VOR, TACAN Only
TERPS	Terminal Instrument Procedures
UHF	Ultra High Frequency
V-ARAIM	Vertical ARAIM
VASI	Visual Approach Slope Indicator
VGLS	Visual Guidance Lighting System
VNAV	Vertical Navigation
VOR	Very High Frequency Omni-directional Range
VORTAC	VHF Omni-directional Range/Tactical Air Navigation
VOT	VOR Test Facility
WAAS	Wide-Area Augmentation System
WRS	WAAS Reference Station

15.0 Appendix C – Navigation System Quantities (as of May 2017)

Navigation System	Quantity	Beyond 20-yr Service Life
High Intensity Approach Lighting System with Flashers (ALSF-2)	153	51%
Direction Finder (DF)	29	100%
Distance Measuring Equipment (DME)	919	100%
High Power DME (HPDME)	469	95%
Low Power DME (LPDME)	450	3%
Localizer (LOC)	1267	71%
Glide Slope (GS)	1139	72%
Lead-in Lights (LDIN)	14	80%
Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights (MALSR)	884	73%
Middle Marker (MM)/Outer Marker (OM)	800	61%
Non-Directional Beacon (NDB)	166	100%
Omni-directional Approach Lighting System (ODALS)	56	100%
Precision Approach Path Indicator (PAPI)	1158	52%
Runway End Identifier Lights (REIL)	718	68%
Runway Visual Range (RVR)	305	89%
Tactical Air Navigation (TACAN)	474	100%
Visual Approach Slope Indicator (VASI)	633	100%
VHF Omni-directional Range (VOR)	954	100%
WAAS Reference Station (WRS)	38	0%

16.0 Appendix D – NextGen OIs dependent on Navigation

RELEVANT FAA STRATEGIC INITIATIVES

Deliver Benefits Through Technology Infrastructure

PBN NAS NAVIGATION STRATEGY FOCUS AREAS

- Operate with PBN throughout the NAS, use the right procedure to meet the need
- Use navigation structure where beneficial and flexibility where possible
- Shift to time- and speed-based air traffic management
- Deliver and use resilient navigation services
- Modernize the FAA navigation service delivery to reduce implementation time
- Enable lower visibility access
- Innovate and continuously improve

NEXTGEN OPERATIONAL IMPROVEMENT/INCREMENTS

RNAV SIDs, STARs, and Approaches [OI 107103]

- RNP Authorization Required (AR) Approaches [107103-12]
- RNAV SIDs and STARs at Single Sites [107103-13]

Increase Capacity and Efficiency Using Area Navigation (RNAV) and Required Navigation Performance (RNP) [OI 108209]

- Metroplex PBN Procedures [108209-12]
- RNAV (GPS) Approaches [108209-19]
- Large-Scale Redesign of Airspace Leveraging PBN [108209-13]
- Transition to PBN Routing for Cruise Operations [108209-14]
- Advanced and Efficient RNP [108209-20]

Resilient PBN Operations [OI 107120]

- PBN Operations using Distance Measuring Equipment [107120-01]
- Alternate Position, Navigation, and Timing PBN Operations During GNSS Interference Event [107120-02]

Other Operational Improvements

- Current En Route Navigation [107101]
- Current Precision Approach, Landing and Departure [107104]
- Current Non-precision Approach and Departure [107111]
- Low Visibility/Ceiling Takeoff and Departure Operations [107115]
- Low Visibility/Ceiling Approach and Landing Operations [107117]
- Expanded Low Visibility Operations using Lower RVR Minima [107119]

PBN PROGRAM (AJV-14) OBJECTIVES/INITIATIVES

Strategic Planning for Performance Based Navigation (AJV-14)

Quality Improvement in PBN Navigation Implementation (AJV-14)

RNAV SIDS and STARs Implementation at Single Sites (AJV-14)

- Complete PBN Implementation activity targets

Legacy Airspace Redesign Using PBN (AJV)

- Complete PBN Implementation activity targets

Atlantic Coast Route Project (ACRP)

- Complete PBN Implementation activity targets

Metroplex (Airspace Optimization) (AJV-143)

- Complete Metroplex activity targets

VOR MON Operational Implementation (AJV-14)

- Provide PBN procedure work to support VOR discontinuance

Implementation Plan for the Route Structure

- Replace conventional jet routes and Victor airways with PBNQ/T routes

NAVIGATION PROGRAM (AJM-32) OBJECTIVES/INITIATIVES

Deliver Benefits through Technology and Infrastructure

- Lay the foundation for the NAS of the future by achieving prioritized NextGen benefits, integrating new user entrants, and delivering a more efficient streamlined NAS
  - NextGen DME Program (G01N.01-02)
  - VOR MON Implementation (N06.01-01)
  - NextGen Navigation Engineering (NNE) (G06N.01-03)
  - ILS Rationalization (TBD)
- Maintain an average daily capacity for Core airports of 59,122, or higher, arrivals and departures
  - Precision Approach Path Indicator (PAPI) (N04.02-00)
  - NavAids—Sustain, Replace, Relocate – (N04.04-00)
  - Sustain DME (N09.00-00)
  - RVR – Replacement/Establishment – (N08.02-00)
  - RVR – ELVO – (N08.03-01)
  - ILS (N03.01-00)
  - VORTAC (N06.00-00)

Make Aviation Safer and Smarter

NAVIGATION PROGRAM (AJM-32) OBJECTIVES/INITIATIVES

Make Aviation Safer and Smarter

- Reduce the commercial air carrier fatalities per 100 million persons on board by 24% over a 9-year period (2010–2018). No more than 6.2 in 2018. FY16 Target: 6.7
  - WAAS and GPS (N12.01-07) (N12.03-01)
  - WAAS Localizer Precision Vertical (LPV) (N12.03-02)
  - Visual NavAids New Qualifiers (N04.01-00)
  - ALSIP (N04.03-00)
- Reduce GA fatal accident rate to no more than 1 per 100,000 by 2018
  - Runway Safety Area (N17.01-01)

LEGEND

- CIP Funded Program
- NextGen PLA/Initiative
- New/Emerging Initiative
- Operations Funded
- Future Project

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