

Navigation Technologies

INTRODUCTION AND CONTEXT

The way pilots and aircraft navigate from point A to point B is rapidly changing. Technological advances in Global Positioning System (GPS) technology and user interface devices are building on each development exponentially to provide pilots with up-to-the-minute information on not only the location of their aircraft, but also the aircraft around them. From the early days of flight when pilots were required to navigate using landmarks to find their way, to the present day technology of highly accurate navigation one foot accuracy and moving maps, changes in technology have incrementally innovated navigation and wayfinding.

The mission of the Federal Aviation Administration (FAA) is to provide the safest, most efficient aerospace system in the world. As the FAA redefines how the National Airspace System (NAS) operates, it is looking for tools, technologies and improvements that can help meet its mission by making the NAS safer and more efficient. As the FAA continues to change how the NAS operates, changes continue to be experienced in the aviation system.

Navigation Types

To understand where the future of navigational aids (NAVAIDs) and technology will lead, the technologies and how they are used must first be understood. There are two specific types of navigation; ground-based NAVAIDs and satellite navigation. Here are specific, commonly used NAVAIDs currently in use in Minnesota and nationally.

Ground-Based Navigation

Instrument Landing System (ILS): An ILS has two components, the localizer, described above, and the glide slope.

The localizer is an antennae array normally located beyond the approach end of the runway and generally consists of several pairs of directional antennas, providing pilots lateral (horizontal) guidance only. The localizer generates and radiates signals that the aircraft instruments determine as left and right of the centerline. The aircraft interprets the signal and displays them on the cockpit indicator guiding the pilot until the runway is in sight.¹ A localizer is shown in Photo 1.

Photo 1: Localizer Antenna



The glide slope operates the same way as a localizer, but providing vertical guidance instead of lateral guidance. In similar fashion, the aircraft instruments interpret the radio based signals and display the relative information to the pilot as either being above or below the designed glide slope. The ILS system combines use of the glideslope and localizer antenna to provide a precision approach with both vertical and horizontal guidance. A glide slope is shown in Photo 2.

¹ https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gbng/ils/

Photo 2: Glide Slope Antenna



VHF Omni-directional Range (VOR): VORs are a ground-based, radio system that provides azimuth information for high and low altitude routes and airport approaches. VORs operate much the way localizers do, with one major exception: VORs transmit azimuth information for 360 degrees, whereas localizers are designed for a specific course to a landing runway end.

Distance Measuring Equipment (DME): DMEs operate with both ILS systems and VHF Omni-directional Range (VOR), providing necessary distance information for pilots. DME equipment in aircraft sends a pulse signal to the ground-based DME. The equipment measures the time it takes for the signal to be received and correlates that into a distance, which is then displayed to the pilot. DMEs only provide distance information. The directional guidance is provided by other NAVAIDs, either the localizer or a VOR.²

Non-Directional Beacon (NDB): The NDB transmits a non-directional radio signal. Aircraft, depending on equipment on board, can either home to the signal, or if equipped with an automatic directional finder (ADF) can set a course to the NAVAID.

Satellite Navigation

Global Positioning Systems (GPS): Satellite navigation is based on a global network of satellites that transmit radio signals from Earth's orbit. Much in the same way the ground-based radio NAVAIDS work, GPS receivers triangulate signals from multiple satellites. By calculating the time it takes to receive the information from multiple satellites, the GPS receiver can calculate the latitude, longitude, altitude and speed.³

How aircraft use GPS technology for navigation depends on the equipment installed in the aircraft and procedures developed by the FAA. GPS receivers installed in aircraft allow for enroute navigation, such as sequencing GPS defined points or simply going "direct-to" a destination. Instrument approach procedures to airports are highly dependent on the aircraft's equipment. For example, Lateral Navigation procedures (LNAV), allow for lateral guidance only, are less accurate, and often have higher ceiling and visibility restrictions. Approaches that include vertical guidance (LNAV/VNAV), provide a glideslope similar to an ILS, but still lack high accuracy. Localizer Performance with Vertical Guidance (LPV) are the highest precision GPS instrument approach procedure, namely due to the more accurate GPS signal through use of WAAS. The Wide Area Augmentation System (WAAS) is an air navigation aid developed by the Federal Aviation Administration to augment the GPS, with the goal of improving its accuracy, integrity, and availability.

NAVAID Use

NAVAIDs, regardless of their type, have one goal: to provide location information for a pilot to maintain situational awareness.

² https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gbng/lpdme/

³ https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/navservices/gnss/gps/howitworks/

NAVAIDs are used in the four distinct phases of flight; departure, enroute, arrival and approach. Each phase can utilize ground-based or satellite navigation. The FAA develops procedures for each phase to accommodate all aircraft. Departure procedures use waypoints that can be defined by ground-based navigation, such as a VOR, or by satellite navigation. Enroute navigation uses the “highway in the sky,” flying specific course from one VOR to another, or by sequencing GPS fixes assigned by air traffic control – also known as “fix-to-fix”. Arrivals, also known as Standard Terminal Arrivals (STAR), use the same infrastructure to consolidate and organize arriving traffic into busier airports. Lastly, instrument approach procedures provide the necessary guidance for aircraft to transition to landing at its destination.

NAVAID Trends

The Shift from Radio Based Navigation to Satellite Navigation

The days of using ground-based, radio NAVAIDs to do a fix-to-fix are over. Technology has allowed pilots to simply type in the waypoint and select, “direct-to,” and navigate to the point in question stress-free. GPS technology has made tasks, similar to this one, safer, more accurate, and efficient. It has reduced pilot workload and allowed for greater situational awareness, so it is natural to understand why this technology has been embraced by the industry.

The trend from ground-based to satellite based navigation has many benefits in addition to the pilot interface mentioned above. The aging infrastructure, high annual maintenance costs, and limited operation budgets have encouraged the FAA to shift from traditional ground-based NAVAIDs to the relatively cost- and maintenance-free satellite technologies. As of 2018, the FAA operates close to 900 VORs, costing the agency nearly \$110 million per year. Most of these VORs have reached the end of their useful life, and estimates for replacement exceed \$1 billion.⁴

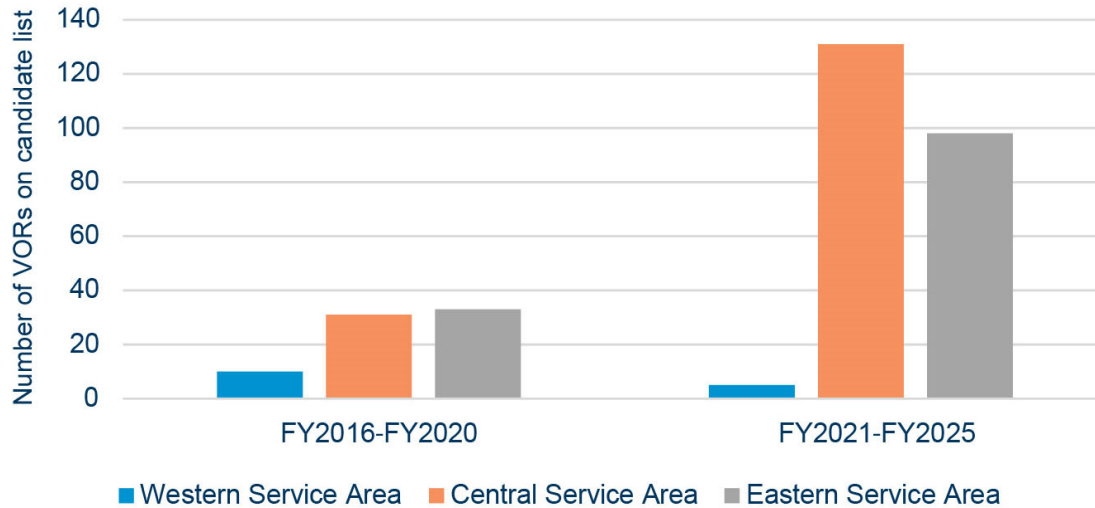
Going forward, the FAA is implementing a strategy to provide a minimum operating network of a core group of 50 VORs, strategically placed throughout the country as a failsafe to GPS unavailability. The minimum network would allow aircraft to proceed safely to a destination with a GPS-independent approach such as an ILS or localizer instrument approach procedure. Current plans show 74 FAA owned VORs to be removed by 2020, and an additional 234 by 2025, which is a 30 percent reduction.⁵

Figure 1 shows the proposed discontinuance of VORs based off their service area. The FAA considered a number of factors for assessing which VORs would be decommissioned.

⁴ <https://www.flyingmag.com/news/faa-plans-major-reduction-vor-coverage>

⁵ <https://www.aopa.org/advocacy/airports-and-airspace/navigation-and-charting/vor-minimum-operational-network>

Figure 1: VOR Discontinuance Candidate List



The FAA has embraced this shift from ground-based to satellite navigation by undertaking NextGen, or the FAA-led modernization of our nation’s air transportation system. The goal of NextGen is to increase the safety, efficiency, capacity, predictability, and resiliency of the aviation network.

As ground-based NAVAIDs become less common, here are some of the technologies that will assist pilots – in both general aviation and commercial service – navigate the skies:

Automatic Dependent Surveillance-Broadcast (ADS-B): ADS-B functions with satellites to accurately observe and track air traffic. Aircraft equipped with “ADS-B Out” broadcast their position, altitude, heading, ground speed, vertical speed, and call sign to air traffic control and other receivers. Aircraft equipped with “ADS-B In” allow aircraft to “see” information on other aircraft, similar to what air traffic controllers can see. Areas that previously had no or poor radar coverage can now have surveillance with ADS-B. Beginning January 1, 2020, the FAA will mandate that all aircraft operating in certain airspace have ADS-B.

Performance Based Navigation (PBN): PBN flight paths are essentially 3-dimensional routes and provide a network to help air traffic managers conduct trajectory based operations. PBN services are laying the foundation for the new NAS, enabling many NextGen operational improvements.⁶

As the FAA implements the rollout of NextGen, there will continue to be a greater reliance on satellite navigation. The FAA is investing in technological improvements, such as ADS-B, to manage greater numbers of aircraft safely and efficiently. NextGen programs (such as Time Based Flow Management) improved multiple runway operations, which along with Performance Based Navigation and ADS-B have delivered an estimated \$4.7 billion in benefits to users of the system. This has resulted in fewer delays and cancellations, increased capacity, reduced fuel consumption, and decreased operating costs. In order for this rollout to continue and be successful, however, the FAA is counting on all users of the system to adapt from more costly, ground-based infrastructure, and invest in their own satellite-based equipment.

⁶ https://www.faa.gov/nextgen/how_nextgen_works/new_technology/pbn/