Courtesy of Peter Eisele

UNDERSTANDING VOR IN THE ERA OF GPS: The Continuing Evolution in the U.S.

by Matthew McDaniel

I ALREADY KNOW WHAT MOST READERS ARE saying to themselves, "Why should I care about VORs anymore?" Global Positioning System (GPS) has become the default form of navigation for all segments of general aviation (GA). In contrast, ILS and RNAV/GPS (with vertical guidance) approaches have become the norm at large and small airports. Chances are, most of us can't even remember the last time we flew an approach without some type of vertical guidance, much less a standard VOR approach. This is especially true when you are talking about flying such approaches in actual Instrument Meteorological Conditions (IMC) down to or near published approach minimums. So, I can appreciate your reluctance to read further, but stick with me here.

The Very High Frequency Omnidirectional Range (VOR) is far from dead (or even dying) and is a critical component to the U.S. navigational network on several levels. Not the least of which is ensuring the ability for instrument equipped aircraft to continue to navigate (both in the en route and terminal phases of flight) should the integrity of the current GPS be compromised for any length of time, for any reason. GPS signal outages are not uncommon. The military intentionally jams (blocks) specific GPS signals regularly for various reasons related to national security and military training exercises. Occasionally, GPS satellites go offline as they reach the end of their life span or are undergoing remote updating or maintenance. Such outages are generally limited in scope and include a heads-up to pilots in the form of Notices to Airman (NOTAMs). But, because the GPS is satellite-based (rather than ground-based, like VORs), it is more susceptible to a variety of less predictable outages, such as cosmic events or malicious enemy attacks. Of course, failures of onboard GPS equipment, related wiring or antennas, etc., are always a possibility, as well. In my 20 years as a Cirrus instructor, I've experienced a total loss of GPS signal a half-dozen times and at least once in each of the factory avionics configurations available through those years.

There is little doubt that Performance-Based Navigation (PBN), Required Navigation Performance (RNP), and various other tongue-twisters related to GPS have changed the landscape of long, short and terminal range navigation. It has made the chores of navigation exponentially easier and safer for pilots. Nonetheless, GPS is not, and never will be a failure-proof system. A ground-based backup system for navigation is critical to maintaining and protecting the National Airspace System (NAS). Maintaining our knowledge and skills related to the use of that backup system is no less critical.

The VOR Revolution

Like many prior navigational advances, the introduction of the VOR was truly revolutionary. It was not dependent upon visual conditions or low altitude flying, like lighted airways and ground markings were. It was not dependent upon the pilot's ability to continually monitor and decipher audible signals, such as the AN Radio Range system was. VOR navigation was not limited to only a few specific courses, such as the Four Course Range. It was not susceptible to atmospheric interference, such as Non-Direction Beacons (NDBs). Nor were the pilots using it nearly as prone to misinterpreting its information and creating dangerous navigational errors. VORs provide an infinite number of precise radials (broken into 360 one-degree segments) the pilot can track to/from the facility with a high degree of accuracy thanks to easy to interpret cockpit equipment (especially compared to some of the earlier nav systems). Its only real limit is range, as dictated by the strength of the facility's signal and the line-of-sight between said facility and the receiving aircraft. VOR navigation might seem quite antiquated now, compared to the precision and ease of today's various forms of GPS navigation. Nonetheless, it was a massive leap forward in technology when it was introduced nearly 75 years ago. Additionally, it has proven to be highly dependable, making it the longest-standing navigation system in the U.S. National Airspace System, with no end date to that streak in sight.

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VOR Expansion

Development of the VOR began in 1937, but it was not until 1946 (soon after World War II) that the first station became operational and well into the 1950s before their installations had become more widespread. While those early VOR stations were combination vacuum tubes and mechanical devices, solid-state technology began to take hold within the VOR network in the 1960s. After that point, VORs became common enough to be adopted as the world standard for air navigation. After the introduction of the VOR, variations in its concept soon developed. Different types of VORs emerged to support different types of navigation. Big and powerful VORs, which could be received 100-plus miles away, were great for use as both en route and terminal navigation facilities, but they were expensive to build and purchase, and also costly to maintain.

Such VORs became known as High VORs and are usable both at low altitude and throughout the U.S. Flight Levels (18,000 to 60,000 feet). Thus, they were used to defining the network of high altitude airways (Jet Airways). Low VORs were used as a cheaper solution to fill the geographic gaps between the cost-prohibitive High VORs. They were used to supplement the VOR network so that additional low altitude airways (Victor Airways) could be developed at less expense. Finally, Terminal VORs exist strictly to support terminal procedures (VOR approaches or to define mandatory intersections on other types of approaches). Terminal VORs are the least expensive, are not used in the Airway networks, and have the most limited range and altitude capabilities.

> *" ... THE CREATION OF THE VOR MON WAS A WELL THOUGHT-OUT PLAN, ALLOWING CRITICAL VORS TO REMAIN ... "*

VOR can also be co-located with other navigation equipment. Distance Measuring Equipment (DME) co-located with a VOR station is known as a VOR/DME and can exist in High, Low or Terminal VOR stations. With the exception of Cirrus aircraft operating in countries where DME is considered mandatory equipment for IFR flight, the vast majority of Cirrus flying today do not carry DME reception equipment on board. Tactical Air Navigation (TACAN) can also be co-located with a VOR, known as a VORTAC. VORTACs including the VOR station itself, DME and TACAN azimuth information (which is used mainly by U.S. military aircraft).

VOR usage as a primary source of navigation has not had a peak point in history. Airlines and high-end corporate aviation began to rely on it less as inertial navigation, OMEGA and LORAN systems became available. Yet, at the same time, those systems were too heavy, complex or expensive to see widespread use within GA, keeping VOR as GA's main navigational tool. Eventually, OMEGA and LORAN systems became more commonplace in lower-end jets, turboprops and GA aircraft, relegating VOR to an en route backup while remaining a primary system for terminal procedures, especially at smaller airports. GPS became popular in smaller aircraft as a means of VFR navigation first; it was not certified for IFR usage until later. Because of the high cost of the initial generation of IFR-certified GPS equipment, legacy airliners often flew on for decades using VOR and ADF rather than the new-fangled GPS navigation. Yet, as we all know, GPS eventually eclipsed all other forms of navigation for terminal, short and long-range and has been the mainstay of Cirrus navigation systems since the first production SR20 was delivered in 1998. Meanwhile, VOR soldiered along, always the trusty backup but all too often ignored by pilots and instructors alike.

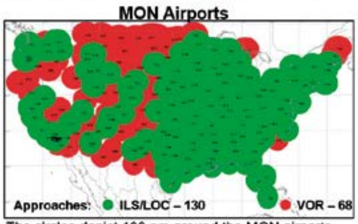
Many speculated the VOR would soon go the way of the Dodo. The rapid development and expansion of GPS and Satellite-Based Approach Systems (SBAS) had been "taking over aviation" (particularly since 2007, when WAAS GPS equipment first began to appear in the Cirrus and GA fleet). Fortunately, the FAA and the various aviation advocacy groups better understood the necessity of maintaining multiple forms of navigational systems. Yes, VOR stations are costly, have range limitations and require maintenance; thus some will be allowed to fade into history. However, a Minimum Operational Network (MON) of them will remain for the foreseeable future.

VOR's Evolution to MON

In late 2011, the FAA published its first notice for public comment related to its proposal to draw down the VOR network within the Continental U.S. (CONUS) to a MON. After the normal process of comment evaluation, proposals and notices was complete, a plan for transitioning to NextGen navigation systems was published by the FAA in July 2016. It included a plan for transitioning to PBN and for establishing a VOR MON. Phase I of that plan was to run from Fiscal Year (FY) 2016-2020. Before Phase I began, the FAA owned 957 VORs. Another 100 nonfederal VORs were also in operation around the U.S. Some VORs were decommissioned during Phase I, but the primary goal during that time was to remove, replace or amend affected Instrument Flight Procedures (IFP), which would allow for more widespread VOR decommissioning during Phase II. By the time you read this, Phase II will have already begun and is currently scheduled to run through 2030. During Phase II, the federal VOR count will fall to 589, but without a significant loss of capability for the average user (see Figures 1 and 2, next page).

The creation of the VOR MON was a well thought-out plan, allowing critical VORs to remain and for an expansion in service volume in many of those. Additionally, a network of Minimum Operational Network Airports (MONA, also

Candidate Discontinuance VORs & MON Airports



The circles depict 100 nm around the MON airports. MON airports ensure that an aircraft is within 100 nm of a location where an LOC, ILS or VOR approach may be flown.

Retained VORs (589)

Candidate Discontinuance VORs (307)

Candidate Discontinuance VORs	
Service Area	VOR #
Western	18
Central	181
Eastern	108
Total	307

VOR Configurations (as of September 10, 2020)				
	Retention #	Discontinuance (Remaining) #	Current Total	Total Discontinued
VOR	16	7	23	6
VOR/DME	214	105	319	48
VORTAC	359	113	472	28
Total	589	225	814	82

Figure 1: *This late October 2020 FAA graphic shows the VOR MON network, as well as the MON Airport network on the left. The geographic makeup of VORs to be decommissioned and the types and numbers of VORs to be retained are charted on the right.*

(Source: faa.gov)

known as "Safe Landing Airports") was established to ensure that, in the event of a widespread GPS outage, all aircraft operating within CONUS would be within 100 nautical miles of an airport with a VOR or ILS approach procedure that does not require GPS, Radar Coverage, DME or ADF to fly legally. Of course, any suitable airport or approach procedure that is even closer at the time of total GPS signal loss may be utilized.

Should They Stay or Should They Go?

It is important for us, as pilots, to fully understand what defines the VOR MON network and what VOR capability changes have developed to facilitate it. First, what criteria was used for decommissioning versus retention decisions? Beyond those VORs used to support ILS, LOC or VOR approaches at Safe Landing Airports, additional factors were applied. Any VOR falling into any of the following categories will be retained:

- VORs that support international oceanic routes
- A sufficient network of VORs to provide coverage at/above 5,000 feet AGL
- VORs in the Western U.S. Mountainous Area (WUSMA) which anchor Victor Airways through high elevation terrain
- Any VOR required for military use
- All VORs outside of CONUS

Additionally, no non-FAA VORs were considered for decommissioning as part of the VOR MON plan. Yet, those VORs

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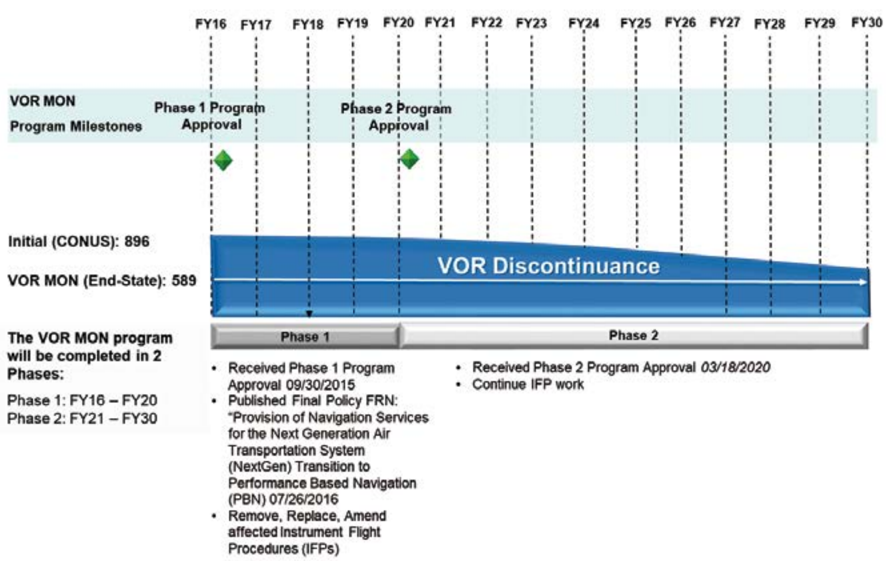

Figure 2: *Timetable of the VOR MON program.*

(Source: faa.gov)

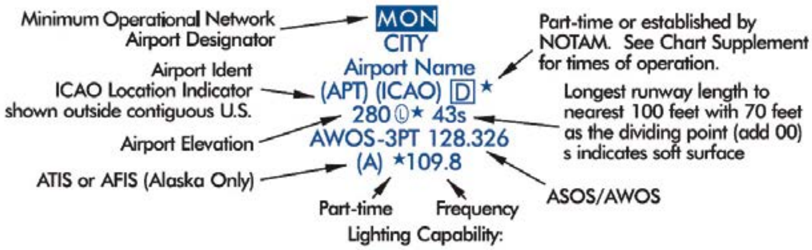

***Figure 3:** Charting example (with descriptions) of a MON Airport on a NOAA (government) Low En route IFR chart.* *(Source: faa.gov)*

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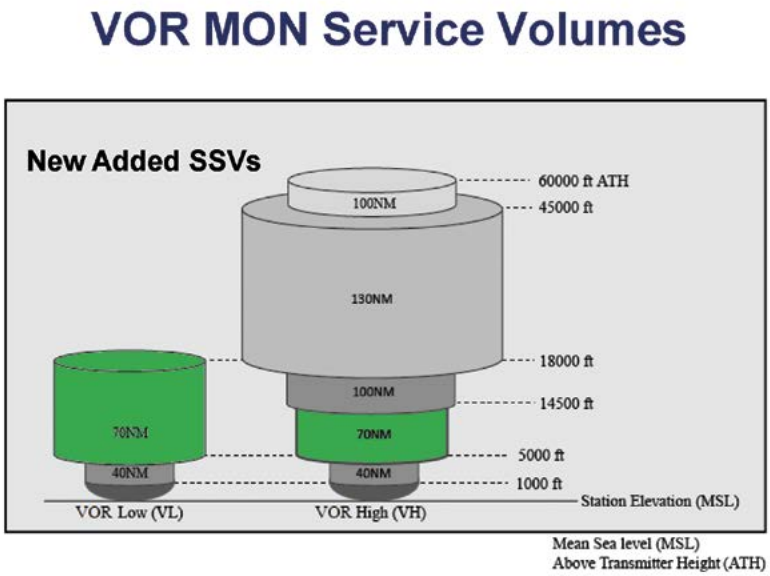
are not part of the VOR MON network either. So, they can be thought of as VORs in addition to the VOR MON. However, since they are not FAA-owned, they could be subject to decommission by their owner/operators at any time. Fortunately, all DME, TACAN and communication capabilities will be retained and reconfigured as necessary, even if the VOR they are co-located with is decommissioned. This will not only protect the integrity of DME and TACAN units (not of great importance to Cirrus pilots), but it also protects communications services, such as Hazardous Inflight Weather Advisory Services (HIWAS) and Remote Communications Outlets (RCO), which are important even to pilots of Technically Advanced Aircraft (TAA).

Conclusion

With the transition to VOR MON and the Safe Landing Airports networks, the FAA has begun implementing some charting changes related to both (specifically, refer to Figure 3, above). To facilitate the reduction in VOR numbers within CONUS while retaining a VOR network with consistent reception capabilities at/above 5,000 feet AGL, two new Standard Service Volumes (SSV) are being added to VORs on the retention list. While these new SSVs do not require major equipment changes, they do represent a change in the SSVs many of us have learned and memorized during initial and recurrent instrument training. Specifically, for High VORs, a 70-nautical-mile

SSV will now exist between 5,000 feet and 14,500 feet Above Transmitter Height (ATH). For Low VORs, the same 70-nautical-mile SSV will extend from 5,000 feet up to 18,000 feet ATH. To see how these new SSVs integrate into the pre-existing SSVs for High and Low VORs, refer to Figure 4, at right.

While the total loss of GPS navigation signal without warning remains a rare occurrence, it is not at all beyond the realm of possibility. When that time comes (without warning or as predicted by NOTAM), will you be ready? Have you studied or practiced navigating solely by use of VOR lately? When was the last time you shot an old-school VOR approach without vertical guidance? When was the last time you had to identify intersections using crossing radials rather than GPS distance? Or thought about reverse sensing, the rule of 60, or the VOR cone of silence? Can you still fly a DME Arc without any help from GPS distance information in your Cirrus? Can you track a VOR radial equally well using the VOR Omni



▲ ***Figure 4:*** *New VOR MON Standard Service Volumes (SSV) added to High and Low VORs are shown in green. Grey SSVs were pre-existing before the changes for the VOR MON project began and will remain on all VORs within the VOR MON network.* *(Source: faa.gov)*

VOR MON TIMELINE:

Establishing a VOR Minimal Operational Network (MON) is part of the FAA's NextGen plan. Phase I ran from 2016-2020 and its primary goal was to remove, replace and amend affected IFPs. Phase II (which has already started) will mainly comprise of decommissioning VORs and is scheduled to run through 2030. When it is completed, the FAA-owned VORs will reduce down to 589 from 957, but without a significant loss of capability.

Bearing Selector (OBS), as you can using a Radio Magnetic Indicator (RMI) needle? Those skills are likely to be woefully unpracticed and unused in the era of GPS. Those are skills that are often never even learned well enough to be retained long term anymore. Yet, they are not skills we can allow to escape our grasp entirely. Grab your favorite CSIP and make sure it is one who is proficient in teaching the skills necessary for skilled VOR navigation. Saddle up your Cirrus or simulator and go pretend it's 1980-something. It will only seem like a futile exercise until your first GPS signal loss on an IMC flight. Then you'll likely be thankful for the VOR MON and MONA networks, your CSIP's tutelage, as well as your commitment to staying proficient in all forms of navigation that your aircraft is equipped for. ⊕

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