

VOR Minimum Operational Network (MON) Information Paper

The following is an abridged version of the information paper on the Very High Frequency Omnidirectional Range (VOR) Minimum Operational Network (MON) presented by the United States in May 2012 at a meeting of the Navigation Systems Panel of the International Civil Aviation Organization (ICAO) in Montreal, Canada.

EXECUTIVE SUMMARY

The United States (US) has announced plans to reduce the Very High Frequency Omnidirectional Range (VOR) based navigation network to provide an alternate means of navigation in case of Global Navigation Satellite System (GNSS) outage. This VOR Minimum Operational Network (MON) should be in place by the year 2020.

The MON will provide terrestrial based navigation at 5,000 ft AGL for VOR equipped aircraft to navigate VOR to VOR and/or to an airport served with an Instrument Landing System (ILS) or VOR approach procedure.

1. INTRODUCTION

The use of the Global Positioning System (GPS) for aircraft navigation has increasingly obviated the need for ground based navigation aids for most domestic flights under Instrument Flight Rules (IFR). The result is that many aviation users no longer use Very High Frequency Omnidirectional Ranges (VORs) for normal navigation over Victor and Jet airways and navigate safely using augmented GPS. As discussed in the FAA's recent Federal Register Notice (FRN) (Reference 1), the United States Federal Aviation Administration (FAA) is planning on a gradual discontinuance of VORs¹ to a Minimum Operational Network (MON) of VORs by the year 2020.

2.0 DISCUSSION

2.1 Future Terrestrial Navigation Infrastructure. The Global Navigation Satellite System (GNSS) has the capability of supporting all phases of flight. With suitable augmentations, GNSS can support all phases of flight with extremely high availability, continuity and integrity. Furthermore, the existing VOR infrastructure provides an overabundance of VORs in the US National Airspace

¹ This paper is concerned with the VOR function of VOR, VOR Collocated Tactical Air (VORTAC), and VOR/Distance Measuring Equipment (VOR/DME) facilities. For simplicity, all of these facilities will be referred to as "VORs."

System (NAS). Recapitalization of the complete VOR infrastructure in the United States (US) would cost in excess of one billion dollars.

To restructure terrestrial based navigation services, the FAA has undertaken the MON project. This project will provide an alternate means of navigation in the event of a GNSS outage. The major elements of the project are:

- a) The reduction in the number of VORs in the NAS.
- b) Provisioning of a minimum network of VORs that will support VOR to VOR navigation and proceeding to airports with Instrument Landing System (ILS) or VOR approach procedures.
- c. Navigation coverage above 5,000 ft Above Ground Level (AGL) in the continental US (CONUS).
- d. Support international arrivals and departures.

2.2 VOR Service Discontinuance. In considering VORs for discontinuance, the goal is to retain an efficient terrestrial based navigation network to meet future aviation needs.

The FAA will convene a working group that will develop a candidate list of VORs for discontinuance using relevant operational, safety, cost, and economic criteria. As part of the process, this working group will engage aviation industry stakeholders and other members of the public for input.

2.3 Purpose of the MON. The purpose of the MON is to maintain an alternate means of navigation capability to provide VOR to VOR navigation service for VOR-equipped aircraft² in case of a GNSS outage. The MON will permit non-GNSS guidance to an airport within 100 nautical miles (nm) that has an ILS or VOR approach procedure. With the MON, all VORs will be retained in Alaska, the Western U.S. Mountainous Area (WUSMA), and U.S. Islands and territories. The WUSMA area and the MON coverage at 5,000 ft AGL are depicted in Figure 1.

A key feature of the MON is that, in case of a GNSS outage, aircraft navigating in the CONUS, outside of the WUSMA, will be able to navigate at or above 5,000 ft AGL and to an airport within 100 nm and land at that airport using non-GNSS-based landing aids, i.e., an ILS, Localizer, or VOR-based approach. Radar vectors, Distance Measuring Equipment (DME) or Automatic Direction Finding (ADF) equipment will not be required for transition to an approach and safe landing at these locations. Aircraft operating in the WUSMA, Alaska, or U.S.

² The term “VOR-equipped” aircraft will be used to refer to non-DME/DME aircraft equipped with a VOR. A backup concept for DME/DME has been developed but is beyond the scope of this paper.

islands or territories will have access to the same VOR infrastructure that is currently provided.

2.4 MON Navigation Coverage. The MON will provide navigation and approach and landing for VOR-equipped aircraft flying under IFR in the case of a GNSS outage, however, VOR-based navigation using only the MON will be less efficient and more time consuming when compared with performance based navigation (PBN). Notional coverage of the MON at 5,000 ft AGL is depicted in Figure 1. The WUSMA is outlined in green.

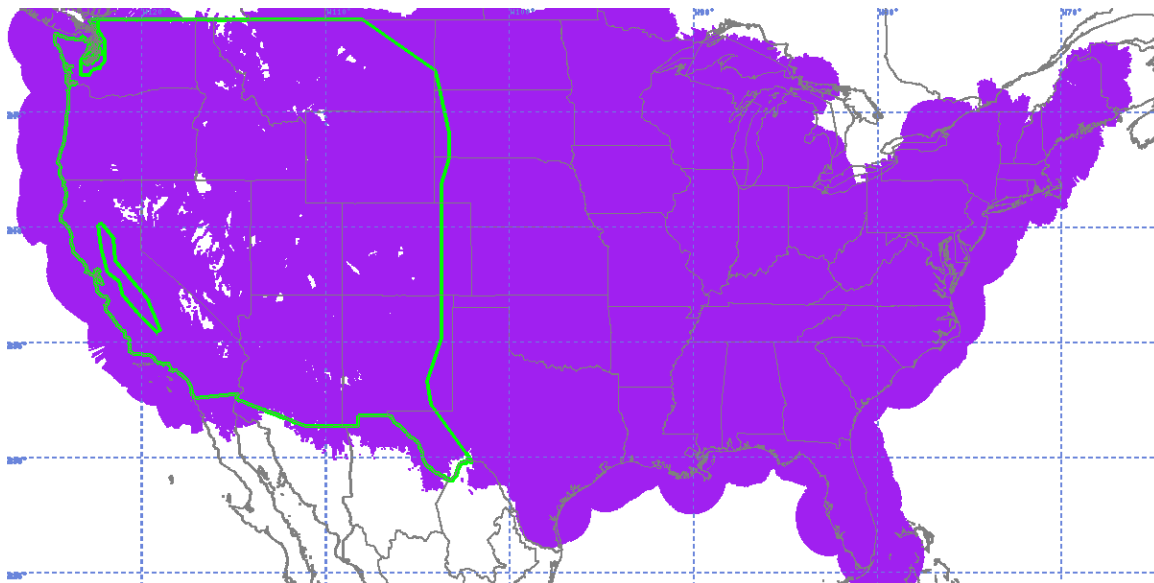


Figure 1. Coverage at 5000 ft AGL Using Notional MON VORs. WUSMA Shown

2.5 Retention of VORs to Support the MON. Table 1 is a summary of the number of VORs retained in a notional MON.

Reason for Retention in the MON	VORs Retained
Western US Mountainous Area	232
Alaska	40
Hawaii	11
Puerto Rico and U.S. Virgin Islands	6
Guam, Samoa, and Grand Turk (1 each)	3
International Routes (Atlantic and Pacific)	20
Support for ILS approaches	192
Support for VOR approaches	57

5,000 ft AGL coverage fillers	34
Core 30 airports fillers	17
Total VORs to be Retained	497

Note: Some VORs are double counted. Therefore the column total is not 497.

Table 1. VORs to be Retained in the Notional MON

The tabled information is notional. The actual number of retained VORs in the end state MON may differ from the tabled values. The target number to be retained is 497.

Reasons for retention include:

- a) MON Coverage.
- b) Navigation coverage in mountainous areas.
- c) Areas outside of the Continental United States (CONUS), such as, Alaska, and island possessions.
- d) Support ILS and/or VOR approach procedures.
- e) Support for International arrival and departure routes.

2.6 Retained and Divested VORs. Figure 2 is a notional graphic depiction of CONUS VORs to be retained for the MON and those that may be divested. Green dots represent VORs to be retained in support of the MON. The red dots represent the VORs that may be divested. The WUSMA is outlined in magenta. The only VOR service to be discontinued in the western US are VORs located in the Central Valley of California and the Puget Sound Area. The large number of VORs to be divested in the northeast is an artifact of the redundancy of the Victor and Jet airway structure in this portion of the US. It is noted that terrain elevation also plays a role in determination of VORs to be retained in support of MON coverage. The goal of MON coverage is navigation coverage at 5,000 ft AGL.

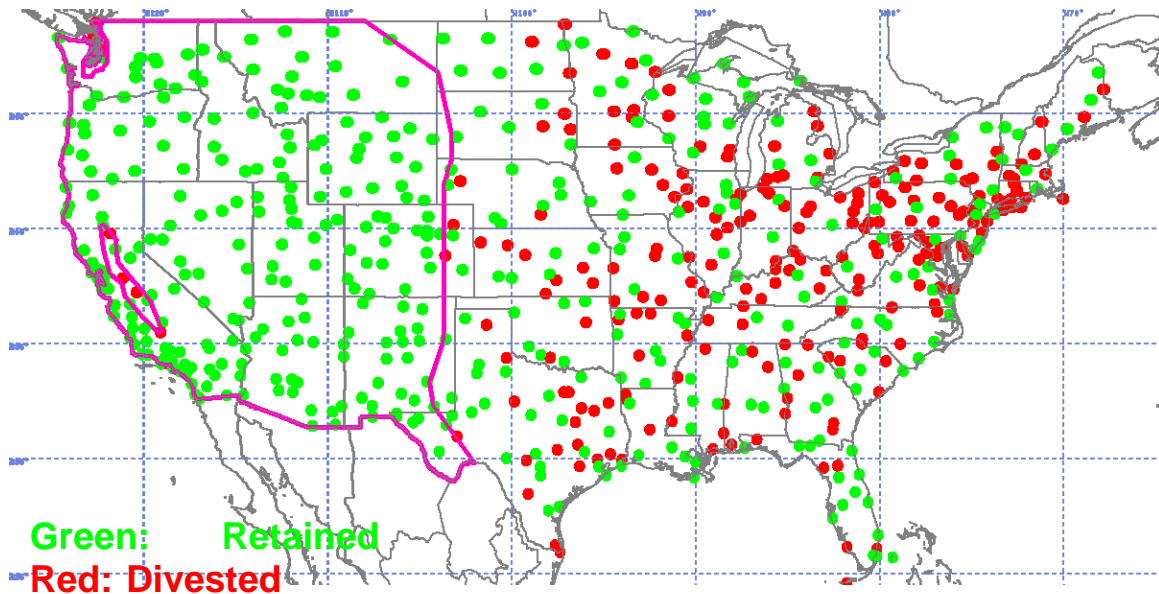


Figure 2. Federally Owned and Operated VORs to be Retained or Divested.

2.7 MON Approach Procedure Coverage. Figure 3 is a depiction of airports where landing capability will be retained for VOR-equipped aircraft. These locations have ILS or VOR approach procedures that do not require radar vectors, DME, or ADF. Each airport is surrounded by a 100 nm green circle if the airport has an ILS- or localizer-based approach and a 100 nm red circle if the airport has a VOR-based approach. Other airports will, of course, be available for landing. However, approaches to other airports may require DME, ADF, or radar vectors.

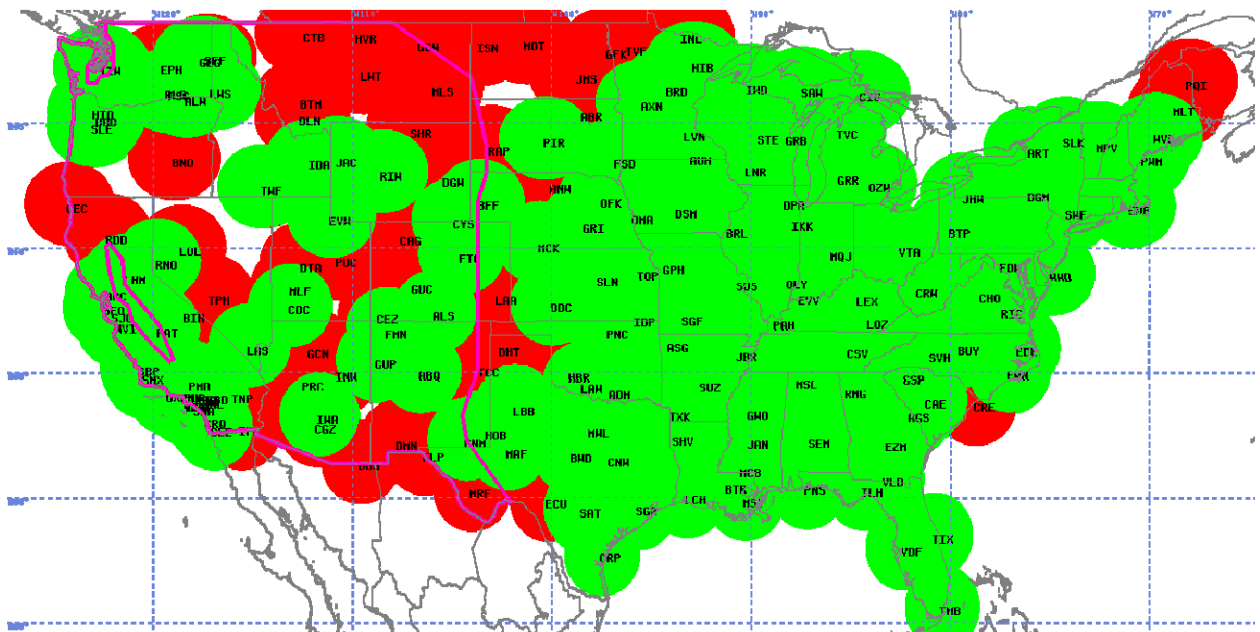


Figure 3. MON Airports with ILS or Localizer Approaches (100 nm Green Circles) or VOR Approaches (100 nm Red Circles).

3.0 Existing and Resulting Airway Structures. A comparison demonstrating the strategic planning for a future terrestrial based navigation infrastructure is made in figures 4 and 5. Figure 4 depicts the existing VOR Airway Structure in the CONUS. Victor Airways are depicted in green and Jet Routes in red.



Figure 4. Existing VOR Airway Structure in the CONUS

Figure 5 depicts the Victor Airways and Jet Routes in the CONUS with the MON, keeping in mind the primary purpose of the MON is to provide VOR to VOR navigation as alternate means of navigation in case of GNSS outage.

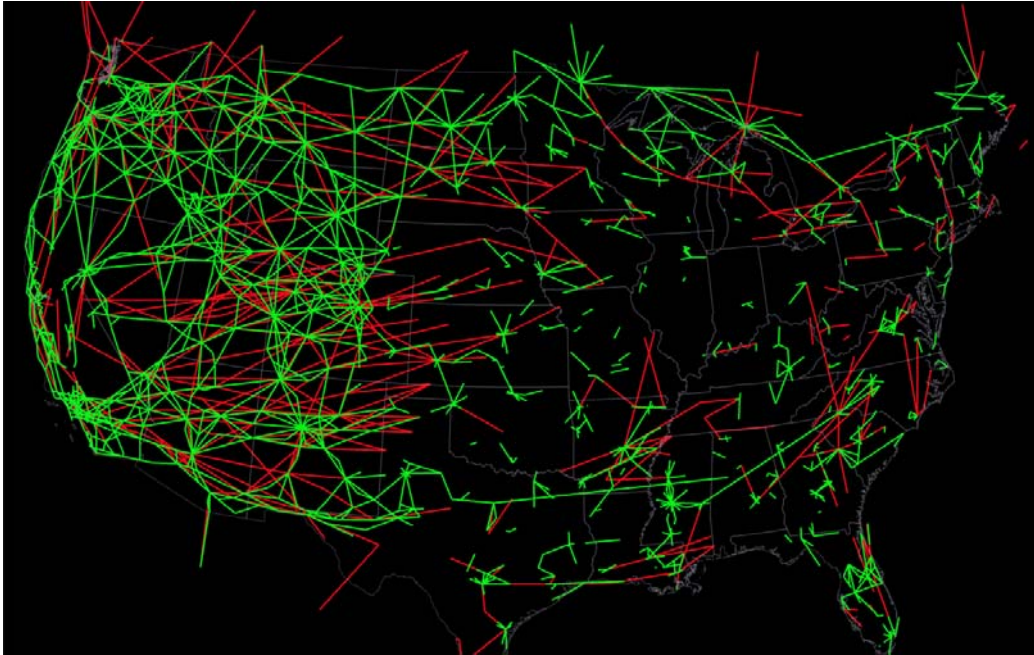


Figure 5. MON Network VOR Structure in the CONUS

3.1 Consistency with ICAO Planning. The MON project is consistent with the ICAO strategy of accelerating transition to PBN with an RNAV and RNP centric airspace system. The MON is anticipated to be an interim step towards further reductions of VORs as alternatives for alternate PNT services evolve over the long term.