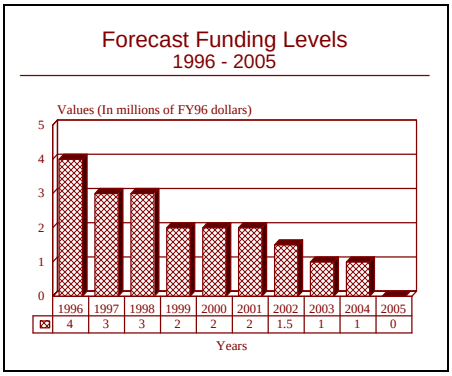
VOR Improvements - Archived 11/97

Outlook

- Ongoing upgrades, enhancements and modifications
- Technology being eclipsed by GPS



Orientation

Description. The prime focus of this program is on upgrading obsolescent tube-type equipment with modern solid-state systems, as well as supporting increased air traffic demands. The program specifically provides for the improvement of FAA en route air navigational and approach aids through the replacement, relocation, conversion and establishment of VORTAC, VOR/DME and VOT facilities.

Sponsor

Department of Transportation (DOT)
Federal Aviation Administration (FAA)
Washington, DC, USA
(Program management)

FAA Technical Center
Atlantic City, NJ, USA
(Research and development support)

Contractors

Canadian Marconi Co
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Ville Saint-Laurent QUE H4M 2S9
Canada
Tel: +1 514 748 3148
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(VOR Test System)

Wilcox Electric Inc.
(Subsidiary of Thomson-CSF)
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Kansas City, Missouri (MO) 64116
USA
Tel: +1 816 453 2600
Fax: +1 816 459 4364
(VOR Improvements - teamed with ITT Avionics)

Cardion Electronics Inc
(Subsidiary of Siemens AG)
100 Sunnyside Boulevard
Woodbury, New York (NY) 11797-2925
USA
Tel: +1 516 921 7300
Fax: +1 516 921 7330
(Solid-State VORTACS for Air Force)

Frontier Engineering Inc
424 Squires Street
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Stillwater, Oklahoma (OK)
USA
Tel: +1 405 624 1769
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(LORAN-C monitors)

Status. Various ongoing upgrades, enhancements, and modifications.

Total Produced. From 1981-1985, replaced VORTAC; 725 units: replaced VOR/DME; 145 units: replaced VOR; 80 units. From 1986-1990, converted VOR to DVOR; 15 units: retrofitted DVOR with RMM and DSB; 50 units: established VOT; 35 units: replaced VOT; 77 units. Scheduled from 1991-1995, establish VOR/DME; 70 units: reinstall DME at ILS; 47 units: convert VOR to DVOR; 25 units.

Of the units listed above, the following represent the solid-state replacement (with embedded remote monitoring and control capabilities) of previous vacuum tube-type equipment: VORTAC - 725, VOR/DME - 145, VOR - 80, VOT - 77.

Application. Improvement of the cost efficiency, reliability, coverage and accuracy of VOR, the principal civil air navigation system, as well as supporting requirements for implementation of the Aviation System Capital Investment Plan (formerly called the National Airspace Systems Plan or NASP).

Price Range. Conversion of a VORTAC to a Doppler VORTAC - approximately US$90,000-$100,000. The CMC Model 8706 VOTs are about US$40,000.

Technical Data

Design Features. VHF Omnidirectional Range (VOR) equipment for azimuth guidance, VOR combined with Distance Measuring Equipment (DME) to add distance information, and TACAN, the military UHF system providing both range and azimuth, are the principal aids to aircraft navigation in use in the continental US today. Supplemented in low-density areas by less expensive nondirectional radio beacons (NDBs), they define the system of civil airways as line segments between navigational facilities. There are approximately 80 VORs, 145 VOR/DMEs and 725 VORTACS in the US today; an additional 70 VOR/DME (Distance Measuring Equipment) installations are planned by the year 2000. The NDB population by 2000 is expected to be 682, including those used as part of instrument landing systems.

Over and above these additions, other related improvement projects identified under the current Capital Investment Plan include adding a RMM (Remote Maintenance Monitoring) capability; adding DME to existing VOR stations, particularly to support nonprecision approaches where neither ILS (Instrument Landing System) nor MLS (Microwave Landing System) facilities exist; adding and replacing existing VOTs (VOR Test) with solid-state VOTs; and relocating, co-locating, and establishing stations to create a better navigation network.

VOR. The broad objectives of the VOR Improvement program have been to reduce high maintenance costs, improve reliability, improve accuracy, increase coverage, co-locate equipment and modify coverage to reflect changing user requirements. The first phase of this program was completed between FY82 and FY89 with the FAA replacing 950 vacuum tube-type VOR and VORTAC systems with modern solid-state equipment. Replacement of conventional VOR with DVOR- first SSB (Single Side Band) and later DSB (Double Side Band) Doppler — is a continuing project to improve accuracy and reliability at approximately 10 percent of the sites located in difficult mountainous or built-up urban regions. Fifteen sites were converted to DSB between 1986 and 1990, with another 25 scheduled to be completed by 2000. Fifty sites had their DVORs retrofitted with RMM and DSB between 1986 and 1990.

VOR/DME. DME service is eventually to be provided at all VOR facilities. Existing vacuum tube VORs were replaced with solid-state VORs between 1981 and 1985. By 2000, new RMM compatible DME systems will have replaced existing DME systems at 40 VOR/DME sites. The removed units are being redeployed to ILS sites. Between 1991 and 1995, 47 VOR only sites were scheduled to be upgraded with DME systems. During the same timeframe 70 VOR/DME sites were also earmarked to be added to (including new VOR/DME equipment) non-Federal takeover sites. VOR/DME facilities are currently in the process of being relocated in order to accommodate route structure changes, real estate considerations, and site suitability.

The VOR/DMEs include an interface with an FAA maintenance processor subsystem. Remote system operation is made possible via embedded microprocessors. Lower total life-cycle software costs will result from the use of Ada software and object-oriented software design, while enhanced accuracy and stability in the monitors will come from the use of digital signal processing.

VOT. VOT facilities provide a signal for in-flight calibration and verification of aircraft VOR equipment. The existing VOTs are being replaced with solid-state versions. A total of 112 sites will receive the new equipment, with 77 of these involving replacement of existing systems, and another 35 being new sites. The new VOTs, replacing two different outdated systems, are

based on the Canadian Marconi Model 8706. Components include a transmitter, monitor, antenna and a remote alarm unit (all meeting ICAO standards). The CMC system works by transmitting a low power signal on an allocated frequency, which in turn supplies aircraft VOR receivers with a null reading for any location within reception range. This allows pilots to quickly and accurately check for proper functioning and correct calibration of his/her VOR receiver. An advantage of the CMC system is that it can be checked almost anywhere on the airport apron, rather than at specific locations (usually at the end of the taxiway), as is the present norm. This reduces waiting and pre-departure engine running time. VOT implementation began in 1991 and was slated to be completed by the end of 1994.

LORAN-C. LORAN-C (Long Range Navigation-C) is a US Coast Guard system originally developed for maritime use. Currently, it is also serving as an interim, supplementary air navigation system in areas of weak signal coverage. Its use provides at least single-level coverage for en-route and terminal IFR navigation for the contiguous US states (in particular a region in the central US called the Midcontinent Gap). Additionally, nonprecision approaches will be supported where signal requirements are met. The FAA estimates there are up to 100,000 LORAN-C airborne receivers in the general aviation fleet (favored because of the low acquisition cost and area navigation coverage which are provided down to the surface, i.e. especially attractive features for general aviation and rotorcraft operations), making it an active and viable system. Demand by the aviation community continues to increase, particularly in low-altitude, remote, and offshore areas not well served by VOR/DME equipment.

The FAA completed studies defining the number and locations of required LORAN-C stations and signal monitors. The establishment of additional LORAN-C stations provides improved signal coverage for the Gulf of Mexico as well as filling in the midcontinent coverage gap with at least single-level coverage. Correction values for nonprecision approaches are provided by signal monitors located at VOR facilities. Implementation was completed sometime in 1992.

Provision of an interface between the monitors and the VOR expands the use of the link used to communicate VOR status, performance and control to also communicate LORAN-C monitor data and status. While the FAA has supplied funding to the Coast Guard for the provision, operation, and maintenance of the transmitters (under an interagency agreement), deployment, operation, and maintenance of signal monitors falls under FAA purview. Approximately 212 monitors were installed, including ones for training, logistics, and field support applications.

Variants/Upgrades

The equipment used to implement the VOR improvement program consists of a diverse list of models supplied by various manufacturers.

Program Review

Background. The early VOR improvement program was based on a study conducted by the University of Michigan to reduce error in VOR usage. The effort subsequently evolved into a full-fledged program incorporating new navigational techniques and equipment. One notable technique emerging from the program was R-NAV (Area Navigation), a method of navigation permitting aircraft to fly any direct course within a ground station's coverage using an onboard computer to calculate the necessary offsets. R-NAV is time- and fuel-efficient, and reduces air traffic congestion immediately over the ground stations. VORTAC is the principal ground system used for R-NAV.

In 1979, the FAA awarded a contract to an ITT/Avionics-Northrop/Wilcox Electric team to develop, build and install 950 new solid-state VOR units for US$115 million. The award was delayed by a protest from Cardion Electronics claiming the FAA relaxed the bid conditions after the bid deadline passed. ITT/Wilcox was the only bidder; others had pulled out because of the restrictive bidding terms . The GAO overruled the Cardion protest.

A 1980 subcontract for US$2.5 million under this program, to Acrian of Cupertino, CA, was the largest single order placed for microwave power transistors up to that time. The new systems featured RMM and fault isolation to the circuit card level, and were forecast to save US$500 million in maintenance costs over a 20-year life cycle. The first unit was delivered to the FAA's training academy in Oklahoma City in March 1982, and used for operational and maintenance training. The final installation, at Lincoln, NE, was completed in August 1985.

During the early 1980s, the FAA considered a plan to transmit ground weather radar imagery to general aviation

aircraft via VOR stations. The plan was dropped in 1983 in favor of a NASP project to transmit limited (severe weather contours only) weather data via the planned Mode S data link. One reason given was that such a display might "lure general aviation pilots" into error.

The FY85 FAA budget plan of US$18.9 million for VOR improvement programs included US$9.3 million to provide 11 new locations with VOR equipment, US$1.3 million to relocate four VOR/DME and VORTAC facilities, US$5.7 million to retrofit DVOR facilities at 54 locations, and US$2.6 million to upgrade various facilities. Two million dollars were budgeted for studies to determine a successor to the VORTAC system for the post-1995 time period.

The FY86 budget request of US$21.3 million for the VOR program included US$14.3 million to convert 32 VOR facilities to DVOR, US$4.4 million to relocate 12 VOR/DME and VORTAC facilities, US$1.6 million to replace VOT systems, and US$762,900 for air navigation system improvements.

In October 1986, a contract worth US$4.8 million for 112 LORAN-C monitor receivers, with an exercised option for 100 more, was awarded to Frontier Engineering of Stillwater, OK. These monitors began to be installed in 1988 to monitor signal integrity, support nonprecision instrument approaches, provide data to forecast changes in signal time differences and provide a data source for NOTAMS (Notice to Airmen).

FY88 plans called for conversion of seven VOR facilities to DVOR, establishment or relocation of 13 VOR facilities, replacement of 27 TACAN antennas and various minor air navigation improvements.

In November 1990, the FAA awarded Wilcox Electric a US$24 million contract for the design and manufacture of 50 new-generation VOR/DMEs, plus site spares and 30 Doppler conversion kits. The contract included deliveries to sites in the US, San Salvador, and the Bahamas Islands (Great Inagua) with the first site being the FAA Technical Center in Atlantic City, NJ.

In early 1991, midcontinent stations became operational and work began on installing LORAN signal monitors at VOR facilities. The interface card design was also completed during this time.

By FY93, all vacuum tube VOR/VORTAC equipment had been replaced with solid-state equipment which included embedded remote monitoring and control capabilities. DME service, however, remained to be provided at all VOR facilities. A network plan was developed to redistribute VORs to meet operational requirements. Tube-type VOR test (VOT) equipment was also scheduled to be replaced with solid-state equipment.

The growing operational requirements that arise in various geographic areas of the US require the establishment of new VHF navigational aid services. Accordingly, provisions have been made to establish 70 VOR/DME sites including new VOR/DME equipment at non-Federal takeover locations. As many as 35 VOT sites were established by the end of 1993.

Related Activity. Remote Communications Facilities (RCF), Direction Finder (DF) systems, LORAN-C monitors, and Automated Weather Observing Systems (AWOS) are being co-located with many second-generation (solid-state) VORTACs. Remote Maintenance Monitoring (RMM) is now required at all combined facilities. Frequency engineering studies have been performed to support these networking concepts. Interfacility communications service is required from the NICS (NAS Interfacility Communication System) and was identified to be provided through the RML (Radar Microwave Link) Replacement and Expansion project. The VOR voice channel will be used to broadcast HIWAS (Hazardous In-Flight Weather Advisory Service) messages, and also may be used to transmit AWOS and ATIS (Automatic Terminal Information Service) data.

On the international scene, in January 1992, Thomson-CSF was awarded a turnkey contract to provide the King Fahd International Airport in Saudi Arabia with air traffic control, navigation, and telecommunications systems. The contract covered the supply of all requisite communications devices, including UHF, VHF, and HF radio equipment; ATXM 4400 digital voice communication control system; as well as navigation and landing aides which included a Doppler VOR, TACAN, and two ILSs.

During FY94, the development of three new Distance Measuring Equipment/Precision Airborne Interrogators was begun by ELTA Electronics (Israel), Alcatel Face (Italy), and Marconi Italiana (Italy). The units will offer advances in azimuth and elevation guidance for all-weather precision approach and landing systems, and will be evaluated to determine whether they satisfy a US Air Force requirement for a ranging source for the Microwave Landing System (MLS), in development in the United States.

Funding

Current funding information is not available. The last available data indicated that the FAA planned to spend approximately US$74.4 million in the FY90-92 timeframe for VOR improvements. In addition, there have been requirements based on activity levels and local situations which are validated on a year-to-year basis. In general, funding for these additional requirements is anticipated to average US$2 million annually.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
DEG Enterprises	$0.1	Jan 1988 - Convert VORTAC to Doppler VORTAC, Memphis International Airport, Memphis, TN (DTFA06-88-C-30014).
G & L Electric	0.1	March 1988 - Convert VORTAC to Doppler VORTAC, Lakeland, FL (DTFA06-88-C-50030).
ISC Cardion	1.2	Sept 1988 - VORTAC spares for FMS (Subcontractor of ISC Def & Space Gp Inc) (F04606-88-C-0950).
G & L Electric	0.1	Sept 1988 - Convert VORTAC to Doppler VORTAC, Raleigh, NC (DTFA06-88-C-30031).
Wilcox Electric	0.3	Dec 1988 - Eleven line items of circuit card assembly, applies to second generation VHF omni range and tactical air navigation (VORTAC) equipment (DTFA02-89-C-89505).
ISC Cardion	3.0	Aug 1989 - Contract to enhance USAF air navigation systems, including VORTAC power monitors, as well as the production of a retrofit kit designed to limit the adjustment range of TACAN transmitters.
Wilcox	24.0	Nov 1990 - Contract for the design and manufacture of 50 new-generation VOR/DMEs with site spares and 30 Doppler conversion kits.
ISC Cardion	5.6	Sept 1991 - Indefinite Delivery REQ, FFP and T&M for the repair of various quantities of spares for the VORTAC-AN/FRN-43, VOR-AN/FRN-44, and TACAN-AN/FRN-45 Navigation Systems (F04606-91-D-0609).

Timetable

	FY72	Government-Industry Symposium on R-NAV
	FY73	FAA approval of R-NAV Task Force recommendations
	FY78	VOR Upgrade RFP released
	FY79	VORTAC production contract award
	FY82	Initial delivery of Improved VORTAC
	FY85	Improved VORTAC implementation complete
	FY86	Retrofit of DVOR with RMM and DSB began
	1987	Award for LORAN-C monitors
	FY88	Establishment/replacement of VOTs began
Nov	1990	Contract award to establish VOR/DMEs
	FY91	Completed installation of LORAN-C monitors. Complete Midcontinent Gap LORAN-C Coverage Improvement
	1991	Began VOT implementation
	1994	Complete VOT implementation
	1995	Complete VOR/DME establishment

Worldwide Distribution

This is a **US** program only.

Forecast Rationale

The currently defined VOR improvement program is an element of the FAA Aviations Systems Capital Investment Plan (ASCIP), a document which can trace its origin back across a name change to the 1970s. Under this plan, VOR and related project improvements are slated to be completed between now and the year 2000. VOR improvements themselves have been just about completed since the end of 1995, although there is a sustained VOR/VORTAC effort carrying on until at least the year 2000. This effort includes ongoing work as well as providing for the enhancement of second-generation technology for RMM retrofits, facility relocations, Doppler VOR conversions, and the modification of TACAN equipment for battery backup and removal of engine generators and associated fuel tanks. The enhancement is required to enable the VORTAC to meet ASCIP operational needs. This includes ensuring that VORTAC, VOR/DME RMM retrofits are compatible with the FAA Maintenance Processor Subsystem.

Even though the original motivation and objectives of the current plan were well founded, the advent and extensive application of Global Positioning System (GPS) technology since the ASCIP was formulated has put a definite limit on the useful life of VOR/DME technology as a navigation aid. In 1994 the FAA abandoned its troubled Microwave Landing System (MLS) development program in favor of a GPS approach, a change which represented a major technical redirection. The application of GPS technology to en-route navigation is a less technically challenging problem than an automatic approach/landing implementation. A GPS air route navigation system offers the potential for significant savings in equipment acquisition costs, and maintenance and administrative expenses, as well as improvements in accuracy which will permit aircraft separation distances to be reduced. This, in turn, will permit the traffic density on heavily trafficked routes to be increased.

VORTAC, as a system concept, has been an ICAO standard since 1959. With over 2,200 VOR/DME and VORTAC stations around the world, it is the most widely used radio navigation system. Viewed as a reliable system offering a low-cost airborne avionics interface, VORTAC has thus continued as the standard radio navigation system into the mid/late term. The present system's reliability — along with such factors as the size of the FAA VOR/DME network, technical validation demonstrations that must still be performed, and military/private sector responsibility issues yet to be resolved — this program will be allowed to run to completion (or at least near completion).

Its technology being eclipsed by GPS, however, VORTAC is heading inevitably into retirement Consequently, funding for the forecast period will be limited to the sustaining funds required to complete the existing program and provide the necessary programmatic support services. An average annual funding level of approximately US$2 million is anticipated.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR FUNDING ($ in millions)

			High Confidence Level				Good Confidence Level				Speculative		
Designation	Application	thru 95	96	97	98	99	00	01	02	03	04	05	Total 96-05
VOR IMPROVEMENTS	CIVIL ATC (FAA)	210.00	4.00	3.00	3.00	2.00	2.00	2.00	1.50	1.00	1.00	0.00	19.50