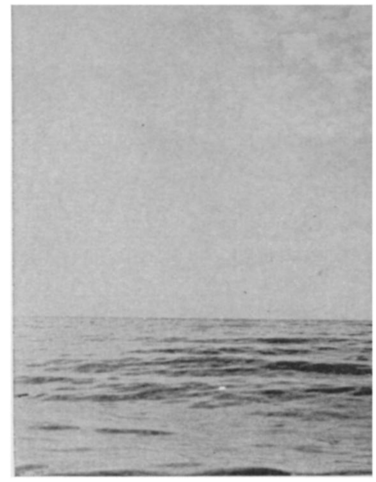

Omega: A navigator's dream

A worldwide low-frequency radio net will offer accurate position fixes to everything from nuclear submarines to commercial airliners

by Charles D. LaFond

Transoceanic navigators have at their disposal today a variety of sophisticated electronic and inertial aids for accurate position determination—if their needs are urgent and their purses are full.

Polaris-missile submarines, for example, are provided with three inertial navigation systems, regularly updated by inputs from a periscope-installed automatic star-fixer, a Navy Navigational Satellite System receiver and other radio-directional aids. New commercial air transports, such as the Boeing 747, carry three inertial systems for long-range navigation. But for a Polaris sub the cost is in the millions and for a 747 the investment exceeds $300,000.

Commercial receivers are available for ocean-crossing vessels to use with the Navy Navsat System; these too are expensive. Such ships do carry other navigational aids—radar, gyro and electronic compasses and Loran—but for accurate navigation the limit for electronics is about 1,000 nautical miles from shore. Reliance thereafter is on the compass, the sextant and dead reckoning for up to another 1,000 nautical miles before electronic aids can again be used. To fleet owners, even small errors in course are costly.

A different approach that significantly lowers user costs, the Omega very low-frequency (VLF) radio navigation system, will come into full global use sometime in 1973. Under development since the early 1950's, the system will use eight transmitters to girdle the world with low-frequency navigation signals that can be used to help guide all aircraft and ships, civilian and military, of all nations. The effort is directed by the Omega Project Office, Naval Electronic Systems Command, in Alexandria, Va.

Although the Omega concept seems simple, implementing the system has required much supporting study and experimentation; many consider it one of the most thoroughly researched projects ever carried out. At present, military and commercial marine receivers are operational, but only a part of the transmitter-station network is built and it is operating at below design power on what the Navy terms an interim basis. Receivers for aircraft use are only now at the technical evaluation stage and will not complete operational testing until next January.

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Trinidad antenna site (scale model).

The Omega concept can be traced back to 1947 when Dr. J. A. Pierce of Harvard University's Cruft Laboratory recommended changes to extend the range and reliability of Loran, a radio navigation system developed by the Massachusetts Institute of Technology during World War II and still in use.

Loran A, the first, operated in the frequency range of two megahertz and had a 100-nautical-mile base line; its successors, Loran C and D operate at about 100 kilohertz and reach out from 150 to 1,000 nautical miles. By very precisely controlling and synchronizing the frequency and time of shore transmissions, a series of electromagnetic bands or lanes are formed every half wavelength between stations by signal cancellation. Loran receivers measure the time differences between the arrival of two signals from stations of known coordinates and thus fix a position on a hyperbolic grid.

Dr. Pierce suggested a study of VLF propagation and measurement of a phase-difference rather than time-difference for possible use in a new Loran-type system. Low-frequency signals, he reasoned, offer inherently longer ranges and are relatively insensitive to electromagnetic interference. Also, VLF signals penetrate seawater from 40 to 50 feet and thus could be received by submerged submarines on station.

Research continued for 10 years, first using a single-frequency system called Radux at 50 kilohertz and below from stations on Hawaii and the West Coast and then a two-frequency system called Radux-Omega at 10 and 40 kilohertz. Optimum frequencies were narrowed to the 10-14 kilohertz band by 1957 and the program became Omega.

Today's system calls for the installation of eight transmitter stations roughly 5,000 nautical miles apart around the world. Each transmits three frequencies (10.2, 11.333 and 13.6 kilohertz) sequentially for 10 seconds at precise times, pulse lengths and intervals for identification. The operational stations will radiate a 10-kilowatt signal to a range of 8,000 nautical miles. (Higher power would increase the range but the system might become self-interfering.)

The four interim-operation transmitting stations are located at Bratland, Norway; Port of Spain, Trinidad; Haiku, Hawaii, and Forestport, N.Y. Westinghouse Electric performed much of the early site surveys, selection and testing for the Navy on the three American-operated stations and also provided their large AN/FRA-31 transmitters. The New York site is temporary and soon will be moved to one now under construction at La Moure, N.D., due to be operational in 1971, according to Omega project manager Capt. James A. Burke.

The Norwegian station was built and is operated by that country. Similarly, the other four stations, it is hoped, will be built and operated by cooperating governments. And therein lies the reason for some of the delay

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in establishing the global network, for the wheels of international agreement move slowly.

For Western Pacific coverage, the Japanese will erect a station on Tsushima Island. Although not yet formally announced, it is believed that Indian Ocean coverage will be provided by the French from La Reunion Island, and that a site for southern South America will be built in Argentina.

Still far from settled is the location of the last station, required somewhere in the Tasman Sea. Satisfactory sites have been located in Australia and in New Zealand but no agreement has been consummated so far. Although Omega will be used by all, it will be a military tool and this fact has been the subject of strong political argument in both countries. Some factions have argued that the presence of such a station could make their homeland a critical target in the event of a nuclear war.

Although these political sensitivities are not yet fully resolved, the technical concept of the Omega system is now well established. When transmitting at the primary 10.2-kilohertz frequency, the grid of hyperbolic curves formed by the signals of two stations creates lanes about 8 nautical miles wide because the wavelength is 16 nautical miles long.

In a low cost or simplified Omega receiving system, lanes must be counted or traced with a strip-chart recorder across numbered lanes. More sophisticated receivers perform lane counting automatically.

By repeating the process, a second line of position can be established; its intersection with the first provides the position fix. Accuracy is limited by the angle of intersection of the two lines of position (90 degrees at best), diurnal and seasonal variations in signal propagation and local geomagnetic anomalies. Measurement corrections based on time, date and location will be provided by tables to limit the daytime error to one nautical mile and nighttime error to two nautical miles. This kind of single-frequency position fix requires about one minute to perform.

Because a submerged submarine might find it difficult to establish positively a particular lane eight miles wide, submarines will be equipped with a two-frequency receiver. The two frequencies combined can be used to generate a hyperbolic grid having lanes 24 nautical miles wide, and the skipper need know his position to only 12 miles.

A high-speed aircraft experiences a different need. At speeds from 9 to 25 miles a minute, a supersonic jet changes its position so fast that the third Omega frequency may be required. The three together provide a family of curves with lanes 72 nautical miles wide. For aircraft, the measurements and corrections must be made rapidly by computers with continually updated positions displayed to the pilot.

Two surface receivers were developed for the Navy, and they are now operational: the AN/SRN-12, a single-frequency multistation unit built by Northrop Corp.; and the AN/WRN-3, a more sophisticated, dual-frequency system, built by ITT Corp. The SRN-12 is the standard unit for surface ships; 140 of them were delivered by Northrop but a subsequent contract for more than 500 units was won recently by General Airtronics, Inc. The ITT system is an all-digital design intended to interact with other more complex navigational systems. Originally planned as a general-purpose system, it will be carried largely by nuclear attack submarines. The newest version is called the AN/BRN-4 and is still being produced for the Navy by ITT.

Numerous commercial receivers are now becoming available priced from $1,000 upward. Northrop units have seen considerable use aboard the Cunard Queen Elizabeth II and the Manchester Liners' Manchester Challenge on Atlantic crossings.

An aircraft Omega receiving system is also being developed by Northrop for the Navy. Two prototypes have been delivered and two more will soon begin service testing. Fully computer controlled, the AN/ARN-99 requires only that before takeoff the pilot enter the Julian date, present position and up to 10 waypoint coordinates. From then on the system gives a new readout of the aircraft's position every 10 seconds.

As part of the Navy's technical evaluation, a receiver was used recently for navigating a patrol aircraft, P-3A, in a 13-hour flight from the Naval Air Training Facility at Patuxent, Md., to Iceland. It arrived only 1.2 nautical miles off the intended target area, a Northrop spokesman says.

Commercial airlines too are interested in Omega as a possible means to reduce the present high cost of inertial systems for long-range flights. Continental Airlines currently is testing a Northrop receiver over its Pacific routes, and the Federal Aviation Administration is planning similar tests over the North Atlantic in the near future.

When the Omega system is completed and fully operational, it is planned that the U.S. Coast Guard will take over the three American-operated stations and manage the entire global system. The present control center is at the Naval Electronics Laboratory, San Diego, but this will later be moved to Hawaii.

A new concept may be introduced into the Omega system to greatly increase its accuracy for some users. Called Differential Omega, it requires the installation of fixed Omega receiving stations at very accurately known locations, within one minute of arc for both coordinates. These sites can then be used to provide correction factors to mobile Omega users within a 200-mile radius of each fixed receiver.

Northrop has studied the feasibility of the technique for the U.S. Army, whose close-support tactical aircraft and long-range artillery have need for improved position determination. Even with present Omega equipment, a Northrop engineer estimates, the technique will provide an accuracy to within 500 feet and with computer refinements to better than 50 feet. □