The Time Web

A synchronized, worldwide network of time promises improved navigation, communication and more.

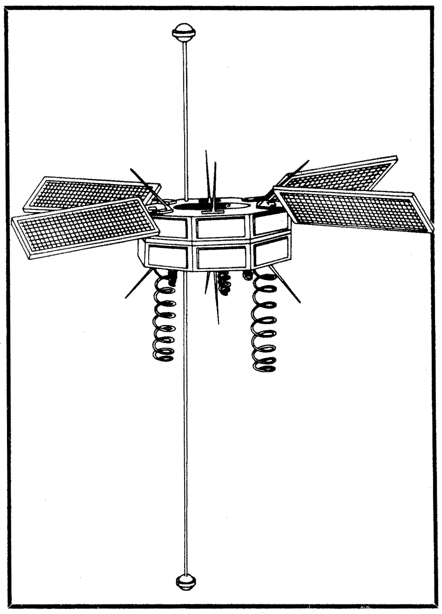
by Jonathan Eberhart

Satellites, atomic clocks, ultraminiature computers and other exotic components are being linked together in an experimental system that will provide much greater navigational accuracy for ships, aircraft and other vehicles. A far broader benefit, however, may lie perhaps 15 years into the future, when communications, collision-avoidance systems and other technologies all are able to make use of a worldwide, synchronized "web" of time.

The seeds of the idea were sown a decade ago when Roger Easton and other researchers at the U.S. Naval Research Laboratory began working on a global satellite navigation system called TIMATION (TIME navigATION). Ever since early seafarers took their first positional fixes, time has been a critical factor in measurements of speed, distance and location. TIMATION uses the billionth-of-a-second precision of a rubidium-vapor atomic clock in a way that promises even supersonic aircraft the ability to measure their position to within the length of a supermarket parking lot.

In the system, atomic clocks aboard high-altitude orbiting satellites continuously transmit timed pulses that are received by appropriately-equipped ships and aircraft. The time required for the signals to reach the craft from two or more satellites can easily be converted into distance measurements, and thence by trigonometry into a position fix. The navigational technique is no different from that used in numerous conventional systems—the difference is the accuracy of the time.

In 1967, a satellite called TIMATION I was launched to check out the principle of the idea—the use of a satellite for passive ranging, in which the ship or aircraft would not have to send out a signal of its own—and to measure the synchronization between satellite and ground-based time measurements (at that time using only a quartz clock). One problem revealed was the effect of atmospheric factors such as instabilities in the ionosphere on the accuracy of the satellite's signal, so in 1969, TIMATION II was orbited with modifications to correct for the atmosphere.



TIMATION III: Weaving the time web.

The success of the design was pointedly demonstrated in two tests of a technique called "time transfer," which simply means the linking of different atomic clocks so that they show exactly the same time. The conventional method had been to synchronize the clocks using a radio link between them. In the TIMATION test, the clock aboard the second satellite was linked first with a clock at the U.S. Naval Observatory in Washington and then with one at the Royal Greenwich Observatory at Herstmonceux, England (a similar test was made last year with the Naval Observatory and the Australian Division of National Mapping). By subtracting the common atmospheric factors in the two linkages, the scientists were able to get the two clocks to within one ten-millionth of a second of each other—an improvement, says Easton, of 10,000 times over the conventional station-to-station hookup.

In recent years, the TIMATION principle has become part of a large triservice program headed by the Air Force, leading up to what will be called the Navstar Global Positioning System. As many as six additional test satellites are scheduled to be launched first, but by the late 1970s or early 1980's, Navstar should be well on its way toward its full complement of two dozen satellites, aranged in these orbits containing eight satellites each, so that the system will be within reach at any time from anywhere in the world.

The first of the remaining test satelites is now scheduled for July 10. Unlike its predecessors, which orbited the earth 500 miles up, TIMATION III (which will also be the first to carry the rubidium-vapor clock) is to be placed in an 8,600-mile-high path similar to the planned height of the operational system. The main reason for the lofty orbits is to give each satellite a greater angle of coverage. Another advantage, however, was discovered when the researchers realized that at the 500-mile height, solar radiation was having a measurable effect on the frequency of the quartz oscillator in the satellite. "Measurable" in this case is only one part in 100 million, but this is a significant amount in a system that hinges on the accuracy of a 6.8-*billion*-hertz oscillation. The higher orbit does not expose the satellites to any less total radiation, but most of the radiation is produced by electrons, rather than by damaging protons. (It was the same kind of proton radiation that affected instruments and caused some data loss during Pioneer 10's flight through the intense radiation belts of Jupiter.)

Beyond Navstar, Easton predicts that the precise orbiting clocks will prove to be a valuable tool in a variety of applications, by providing the entire planet earth with a single, accurate time system, enveloping the globe in a web of synchronized satellite signals. Collision-avoidance systems, for example, could be made much more effective if aircraft and ships were all continuously updated with position information in the same reference system. Military communications might be able to use the synchronized time net to encode and decode messages by dovetailing them within one another.

The time web is on its way. □