SERIES

TECHnically Speaking

BY PETER ASHFORD

Navigation: Past and Present

Navigation has developed throughout the years using the natural elements surrounding us: the stars, the clouds, the tides. In the days of Columbus, rubbish or flotsam was used, along with song, to determine the speed of a sailing ship. Primitive maybe, but it worked.

In Micronesia, there were successful navigators who also relied on the natural elements and could even predict the weather, although they enlisted the help of superstition.

Since the 1920s, electrical impulses and radio waves guided navigators to their destinations, followed by the development of airways and navigation aids. World War II saw the advent of radar and more accurate navigation techniques.

Moving into the modern era, Doppler and inertial navigation systems are the norm for today's aircraft navigation, and space navigation has allowed us to travel to the moon and the planets, offering new and exciting areas to be explored.

When modern travellers board an international flight from Auckland International Airport bound for Los Angeles, San Francisco, New York or London, when they disembark, they expect to be at their chosen destination. They sit in the cabin with their drinks and meals, not really concerned with why the aircraft might be making slight changes in direction. They assume the flight-deck crew know what they are doing.

The key word for their successful and safe journey to their final destination is "navigation."

Navigation is defined in the Chambers 20th Century dictionary as, "The act, science or art of conducting ships or aircraft, especially the finding of a position and determination of a course by astronomical observation and mathematical computation."

Navigators used various methods to achieve their goals using the above methods.

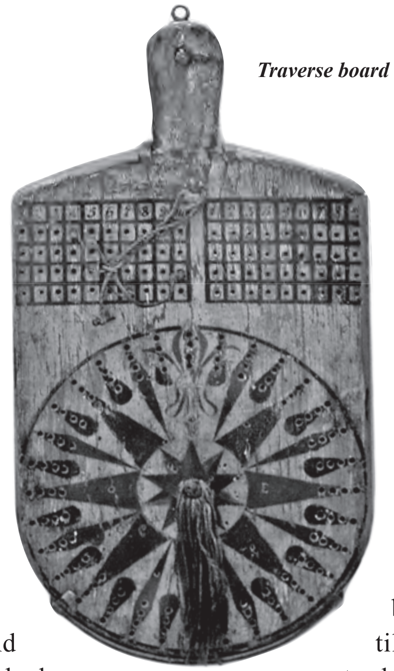
The Past: Columbus and Dead Reckoning Navigation

At the end of the 15th century, celestial navigation was just being developed, primarily by the Portuguese. Prior to the development of celestial navigation, sailors used "deduced" or "dead reckoning" navigation. Christopher Columbus and most other sailors of his era used this method.

In dead reckoning navigation, the navigator found his position by measuring the course and distance he had sailed from some known point. Starting from a known point, such as a port, the navigator measured out his course and distance from that point on a chart, pricking the chart with a pin to mark the new position. Each day's ending would be the starting point for the next day's course and distance measurement.

For this method to work, the navigator needs a way to measure the distance sailed. Course was measured by magnetic compass, which was known of since at least 1183 in Europe. Distance was determined by a time and speed calculation: the navigator multiplied the speed of the vessel (in miles per hour) by the time travelled.

In the days of Christopher Columbus, the ship's speed was measured by throwing a piece of flotsam over the side of the ship. There were two marks on the ship's rail, which were a measured distance apart. When the flotsam passed the forward mark, the pilot would start a quick chant, when the flotsam passed the aft mark, the pilot would stop chanting. (The exact words to such a chant are part of a lost oral tradition of medieval navigation). The pilot would note the last syllable reached in the chant and, using a mnemonic,



Traverse board

would convert that syllable into speed in miles per hour.

Unfortunately, this method would not work when the ship was moving very slowly because the chant would end before the flotsam had reached the aft mark.

Speed and distance were measured every hour. The officer of the watch would keep track of the speed and course by using a toleta, or traverse board, which was a pegboard with holes radiating from the center along every point of the compass. The peg was moved from the center along the course travelled for the distance made during that hour. After four hours, another peg was used to represent the distance made good in leagues during the entire watch. At the end of the day, the total distance and course for the day was transferred to a chart.

Most historians believe Columbus was the first sailor to keep a detailed log of his voyages; however, only the log of his first voyage survives in any detail. It is from these records we learned how Columbus navigated and it's how we know he was a dead reckoning navigator.

Some scholars believe Columbus was a celestial navigator who kept his celestial records hidden for some reason. (This supposition is necessary to support some theories of the first landfall). This hypothesis, however, does not hold water. Columbus's ships were steered by helmsmen at a tiller below the quarterdeck. The helmsmen could not see the sky, so the only way they could keep a course was by magnetic compass. The officer of the deck had his own compass and would call down course changes as necessary; this means, courses recorded in the ship's log would have been magnetic courses.

Navigation in Micronesia

Before Europeans entered Micronesia, the known world of Carolinean Island navigators extended from Palau and Yap in the west to Ponape in the east, and from Saipan and Guam in the north to Nuquoro and Kapingamarangi in the south.

Their sailing directions also included places beyond this region in the west, south and east, but these were outside the limits of intentional voyaging and most were mythical rather than real places. Knowledge of such distant places met no practical need; it only served to show off one's learning.

Within Micronesia, the low

Continued on following page

Continued from page 81

islands of the coral atolls are where navigation and seafaring have been known and practiced. People living on the high islands of this region—Palau, Yap, Truk, Ponape and Kosrae — did not maintain seafaring traditions and depended on the atoll dwellers for trade and ocean travel. Pulawat, Pulap and Satawal, all west of Truk, were where Carolinean navigation was most highly developed and where it continues to be in active use today.

Basic to the entire navigation system is the "star system," or "sidereal compass" as the navigators called it. Observed near the equator, the stars appeared to rotate around the earth on a north/south axis. Some rose and set farther to the north and some farther to the south, and they did so in succession at different times.

The "star structure" divided the great circle of the horizon into 32 points where the stars (other than Polaris, for which the points are named) are observed to rise and set. These 32 points form a sidereal (star) compass, which provided the system of reference for organizing all directional information about winds, currents, ocean swells and the relative positions of islands, shoals, reefs and other seamarks.

The diametrically opposite points of this compass were seen as connecting in straight lines through a central point. A navigator thought of himself or of any place from which he was determining directions as being at this central point. Thus, whatever compass point he faced, there was a reciprocal point at his back.

Weather conditions are equated with the months of a sidereal calendar. Though called "moons," these months were independent of the moon.

In most calendars, there were 12 or 13 months of unequal length, each named for a star. A month began when its star stood about 45 degrees above the eastern horizon just before dawn, when one wanted to look at it, he would tilt his head back to where he feels a roll of skin forming on the back of his neck. The month continued until the next month's star reached the same position.

After each month began, one or two "fighting stars" made their first appearance above the eastern horizon just before dawn. If there was one such star in the month, it would "fight" (bring stormy weather) for five days after the next new moon appeared in the west at sunset. If there was another fighting star in the same month, it would make stormy weather in the last five days of the moon's cycle that began in that month. What was a fighting star in one month might be the star for which a subsequent month was named, but not all fighting stars designated months. More immediate weather conditions were forecast from the color of the sky at sunset and sunrise as well as the shapes of the clouds.

The Navigator as a Ritual Specialist

Protective ritual was another part of what a navigator had to learn. He was said to be the "father" of his crew, who depended on him for their welfare.

Properly invoking patron spirits of navigation, carefully observing necessary taboos, employing spells to prevent storms and ward off sharks, and providing protective amulets for the vessel were among a navigator's responsibilities and among the things he must learn. He also needed to know enough of the special rhetoric and spells associated with politics and diplomacy to ensure hospitality and safe conduct for himself and his crew on arrival at other islands.

Such knowledge was especially useful where voyagers did not have kin connections and where people likely were suspicious and even overtly hostile. Their ritual knowledge set navigators apart.

Modern Times

Since the early days, navigation techniques have progressed rapidly to the modern navigation systems of today. In 1909, Bleriot crossed the English Channel; in 1911, Calbraith P. Rodgers made a trans-America flight; and in 1913, Roland Garos became the first person to cross the Mediterranean.

In 1920, the United States Navy carried out an experiment of interest to aviators all over the world. A U.S. Navy Curtiss F5L flying boat flew from its base at Hampton Roads near Norfolk to the old battleship USS Ohio stationed 130 miles out in the Atlantic, then returned to base.

What was special about this flight was the pilot was able to steer straight to the battleship thanks to an electromagnetic cable lying on the seabed. A special receiver installed on the Curtiss picked up the signals from the underwater cable. Using this system, the crew simply had to follow the course indicated by the signals. Whenever these signals were interrupted, the crew knew they were off course, while a constant signal meant the aircraft was on the correct heading. This simple new electromagnetic cable system could be used to keep pilots and navigators from becoming disoriented while flying at night or in thick fog when they could not see the ground (Perhaps the beginning of IFR?).

During World War II, bomber pilots had been desperate for an efficient and accurate navigation aid, and in January 1943, the requirements appeared to have been met. A system known as "Oboe" was used by Mosquitoes of the Pathfinder force, which flew ahead of the bombers. The system involved radio pulses from two stations in England to establish the location of the target. The stations guided aircraft along the exact arc of a circle passing over the target. About one minute before bomb release, the pilot heard sequences of dots and dashes, followed by one long dash. He released his bombs at the end of this transmission. The "Oboe" system was accurate to within the size of a factory.

The first airborne navigation aid (nav-aid) was the direction finding (DF) loop — a conductive coil that could be rotated until the received signal from a ground radio station was reduced to zero (known as the null position) and the was loop at 90 degrees to the position of the ground station. Navigators could obtain DF bearings on two ground stations in quick succession and, by drawing two lines on a map, obtain a "fix" (a known aircraft position).

Today, the successor of the DF loop is the automatic direction finder (ADF) in which an intermediate bearing to any selected ground station is indicated on the ADF indicator.

Airways

In the late 1920s, the United States began a nationwide system of airways, which survive today and now encompasses the globe. At first, each airway was a single radio beam sent out from a ground station and pointing to the next. At the ground station, there were four aerials, two of which continuously transmitted the Morse letter A (dot dash), while the other two aerials transmitted the letter N (dash dot).

Continued on following page

TECHNICALLY SPEAKING
Continued from page 83

As the dots and dashes were keyed precisely together, the two signals merged along the center line of the airway into a continuous note. If the aircraft was just off the center line, an A or an N would be heard, while passing directly over the station caused the signal to disappear entirely for a short time.

The system was called "radio range," and it was the basis for airways worldwide until after 1945. The obvious drawback was it provided only two or four routes to fly. The next step was to build a very high frequency omni-directional radio range (VOR). This combined two sets of precisely timed radio signals in such a way an indicator in an aircraft could immediately show the bearing from each VOR station. But again there were severe limitations.

VOR gave no help in using the whole of the airspace, and again restricted aircraft to congested airways, which might not be the route the pilot wanted to fly. A separate device called distance measuring equipment had to be used to give range information.

In the years after 1945, the British Decca Co. saw a future need for a refined RNAV system that would be usable over the entire airspace system right down to sea level. It would have extremely high accuracy to assist in the same control of dense traffic right down to the instrument landing system on approach to the runway.

A hyperbolic system was developed, using continuous radio waves instead of pulses, emitted by a master and three slaves. At first, navigators had to plot their position on special hyperbolic maps using three sets of dials called decometers.

However, by 1951, the aircraft track could be plotted automatically on a moving map called a flight log, which gave, for the first time, an exact picture of aircraft position at all times.

Two of the nav-aids on all large transport aircraft do not require any ground stations and are self-contained in the aircraft. Doppler radar uses the Doppler shift in the frequency of a signal caused by motion of its source relative to an observer. To help understand this principle, it is the way the pitch of a fast-moving noise, such as a train whistle or low-flying aircraft, sounds higher as it approaches and lower as it departs.

The aircraft transmits radio waves in a fan of four narrow beams, which strike the ground and are reflected back to the aircraft. By exactly comparing the shifts in frequency of the reflected signals, the airborne navigator can determine track and speed over the ground. Thus, no matter what the wind might be, the position of the aircraft is continually updated.

The other self-contained nav-aid is the most valuable of all. Inertial navigation systems (INS) could not be produced until technology existed to make gyros and accelerometers with an extremely high accuracy, far more precise than the parts of the most expensive watch.

The INS uses three sets of accelerometers, which in effect are much more accurate counterparts of the simple pendulum. They continually measure and record the acceleration of the aircraft in the fore/aft, up/down and horizontal directions. Extremely accurate gyros are used to hold the accelerometer platform exactly level relative to the earth below. Even a very small tilt would be interpreted by the accelerometers as a false acceleration.

A modern INS platform is held level with the same accuracy as would be needed to point a light beam at a small coin 0.5km (0.31miles) away, while accelerometers could measure the acceleration of a car that took three hours to go from rest to a speed of 40 km/hr (25 mph) — not a car I would buy.

Doppler and INS have made the most advanced aircraft able to navigate with great precision anywhere in the world and without outside help. However, there are many other navaids available for all kinds of operations. Some are simple and aimed at the private pilot. Some use satellites orbiting the earth. Omega is one of the more common, a hyperbolic system using very low frequency signals and able to cover the entire globe with only eight ground stations.

As far back as we can remember, man has had a need to travel from point A to point B. Early methods of navigation were known to work, but now are considered primitive, yet many of today's sophisticated navigation techniques use the same principles.

But what of the future? We already have been to the moon; we have landed equipment and sent pictures back from its surface. We now can live in space (space stations). We might, in the not too distant future, be visiting the actual stars the early navigators used to help them travel the relatively short distances on earth.

I see the next great challenge for the navigator as inter-space navigation and even inter-galactic travel — an exciting prospect. ❑

If you have comments or questions about this article, send e-mails to avionicsnews@aea.net.