CELESTIAL NAVIGATION

PHILIP VAN HORN WEEMS*

Captain, United States Navy (ret.)

(Read April 23, 1954)

SINCE the science of celestial navigation has had more than two centuries of development involving astronomy, mechanics, physics, and mathematics, no attempt will be made to cover the entire subject. Rather, I shall describe briefly its practical beginnings about 1734, its status in 1800, in 1900, and at present, and then indicate some possible future developments.

The urgent need for better navigation mothered twins—the sextant and the chronometer—about 1734. This advance was so great and the need so fully met that by 1800 celestial navigation methods became standardized. Relatively few changes were made in the nineteenth century, though special credit is due Sumner and St. Hilaire for their valuable contributions. Celestial navigation at sea may be fairly dated from the inventions, at nearly the same time, of the sextant and of the chronometer.

Since the only practical means for determining longitude requires an accurate timing device, there was no means for determining longitude at sea until Harrison in 1735 built his chronometer No. 1, which is still in running condition at Greenwich, England.

The sextant was invented nearly simultaneously, and independently, by Thomas Godfrey of Philadelphia and John Hadley of England about 1733. This was such a great advance over the old cross-staff that it is believed that even an authentic model of the latter does not exist today.

To supplement these two observing devices, appropriate tables and a better nautical almanac were needed. By 1802, Bowditch supplied excellent nautical tables, with the result that celestial navigation became standardized and sufficiently accurate to meet the needs of the mariner. The practice of navigation in 1900 was not greatly different from that of 1800. The same vernier type sextant was in use with moderate improvements; Percy L. H. Davis had his improved haversine tables, and there was a clearer understanding of the celestial line of position. The method of timing observations was little changed. The almanac and the nautical tables in 1900 still catered to navigators using lunar distances, though I have never known a navigator who knew a person who made practical use of lunar distances.

Since 1900, we have had radio communications, but the navigators in general stuck to their elaborate chronometer comparisons, with their first and second differences and complicated chronometer corrections.

The turn of this century saw in use on larger ships: (1) the vernier sextant; (2) three chronometers, carefully rated and compared, with time checks by the "time ball" in port; (3) the American Nautical Almanac, using "Astronomical Time," and including data for working "lunars"; (4) American Practical Navigator, by Bowditch with some of the tables a century old.

Soon air navigation supplied the need, and the radio the means, for radical improvements in celestial navigation. As marine navigation methods were streamlined for air navigation, the innovations were later adopted by mariners. Some of these developments include the following matters:

1. Timing of observations has been improved by the use of radio time signals and the second-setting watch, giving Greenwich mean time by direct reading. The three chronometers formerly used have been reduced to one, and this is used normally as a check only, since the navigation watch is checked and rated by radio time signals, and set to the exact second of Greenwich mean time. The *timing* of observations is one problem which has been satisfactorily solved. If the sextant observation for altitude could be made as ac-

* On November 13, 1953, the Society in Executive Session voted to award the Magellanic Premium to Captain Weems in recognition of his invention of methods and instruments for celestial navigation. The Magellanic Medal was presented to him on April 23, 1954.

curately as we can time it, the observed data would then be nearly perfect, say to within one hundred feet.

2. The vernier of the old marine sextant has gradually given way to the ***micrometer drum,*** and the bubble sextant with averaging device has been developed for air navigation.
3. Special tables have been published which cater to the needs of the navigator. These tables speed up and greatly simplify the process of reducing observation to position.
4. The nautical almanac has undergone radical changes by incorporating the features of the air almanac.

Since time does not permit an account of each development, I shall discuss the air almanac. Partly by accident and partly by inclination I have contributed personally to its modern development.

In 1928 at Charles A. Lindbergh's request, I had a month's leave from the Navy in order to teach him celestial navigation. I reported to Major Tom Lanphier at Selfridge Field in Michigan. While working sun lines of position for practice, Lanphier pointed out the weakness of advancing a sun line for approximately an hour's run to cross with a second line to obtain a running fix. We in the Navy had, of course, known about this weakness of celestial navigation, but it hadn't occurred to us to do anything about it. Lanphier's observation was a challenge, and, as a result, I began to study the problem. A few days later in a Washington hotel, I awoke about four A.M. from an apparent dream with the idea, "Why not simplify moon sights by tabulating the moon's right ascension and declination against sidereal instead of mean time in order to save the conversion of mean to sidereal time?" To make certain I would not forget the idea, I wrote it down immediately. However, this was unnecessary since it was on my mind when I awoke about seven o'clock.

The idea still seemed sound to me, but it would be ludicrous to go to the hydrographer with the story, "I woke up last night with an idea." I compromised by saying as casually as I could, "Recently I had an idea of speeding up moon sights." To my pleasant surprise the hydrographer saw nothing wrong with the idea. I then wrote an official report on the subject, and later went to the Naval Observatory where the superintendent gave me every encouragement. I wrote a second report on the subject and started work on producing the new moon data.

Several friends, the late Rear Admiral I. C. Sowell, Vice Admiral M. F. Schoeffel, Vice Admiral J. E. Ginrich, and others offered helpful suggestions such as giving right ascension in *arc.* I wrote Dr. Ogura in Japan about our problems. He answered, "I do not see why you do not use Greenwich mean time in the first place."

So it went, one faltering step at a time. Before Dr. Ogura's letter was received, the practical solution came to me while I was pacing the deck of the U.S.S. *Cuyama:* "For each selected interval of Greenwich mean time, compute and tabulate the moon's Greenwich hour angle in *arc.*" I made official reports after each improvement. Finally in September, 1929, appeared "The Lunar Ephemeris for Aviators" giving the moon's Greenwich hour angle and declination for ten minute intervals of Greenwich mean time. Later this plan was extended to the sun, planets and stars. The first "Air Almanac" of my design appeared in 1933, and was discontinued in 1934. In 1936 the idea was suggested to the British, who published it in 1937. I then published it under license in the United States. Finally in 1941 the United States started regular publication of the "Air Almanac." Now the British and U. S. publish it jointly.

VISION OF THE FUTURE

Billions have been spent and thousands of inventions have been made of electronic equipment within the past fifteen years. As a result of this tremendous effort, great progress has been made. Even so, because of the fact that electronics methods may be jammed, lack of availability, cost and weight, and lack of accuracy under certain conditions, electronic methods do not yet fully meet the requirements for sea and air navigation.

Progress in celestial navigation has slowed in recent years and much-needed research and tests in this field would probably pay good dividends for effort expended. Celestial navigation suffers from age. It has sufficed for the mariner for so many years that many seem to think that it is a fully developed art and needs no further development.

The following items should undergo research and careful tests: (1) refraction and irradiation; (2) deflection of the vertical; (3) coriolis effect; (4) acceleration.

Refraction tables, especially for low altitudes, are to some extent uncertain. An urgent need exists for systematic, controlled tests to determine values of refraction under various conditions of temperature, pressure, and especially of terrestrial refraction which appears in the dip of the horizon. Perhaps this Society could help in this important work.

As research and tests improve the art of celestial navigation, its application should be greatly improved by combining electronic controls to celestial observations. After all, electronics, per se, do not suffice for our purposes. A selenium cell will control the opening and closing of a door, but we need the door and the power to operate it.

If we have a precise gyro, electronic methods for controlling it will do wonders, but we must first have the gyro. In the earth itself we have a most accurate gyro. Furthermore we know the positions of numerous heavenly bodies so accurately that when these positions are translated to the earth, we can fix our position to within an area the size of this room. We survey our lands with great precision by establishing fundamental positions by celestial observations. Once a position is accurately established, we can do wonders with electronic and other methods in determining *relative* positions.

Navigation in the future would benefit by utilizing the positions of heavenly bodies so accurately determined by astronomers together with the art of the practical navigator aided by electronic methods of control.