Science and Seventeenth Century Navigation

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Until the advent of electronic navigational devices there had been only two important techniques for determining a ship's position when out of sight of land: dead-reckoning and celestial navigation. Dead-reckoning consisted of cumulative plots of distances and direction of travel on a plane chart. The navigator plotted each segment, beginning at the end of the previous segment and, if his information concerning the ship's progress were correct and, if he had plotted carefully, he was able to make an accurate estimate of his position at any time. Information concerning the ship's progress was supplied, in part, by the ship's compass but, for the most part, the navigator had to rely upon his own skill in estimating speed, leeway, and the effect of currents.[1] The theoretical framework upon which celestial navigation was founded was at least as old as Ptolemy's *Almagest*. In parts three and four of Book I, Ptolemy hypothesizes the spherical movement of the heavens and the sphericity of the earth. As arguments for these hypotheses, Ptolemy asserted that the differences in the recorded times of observations of celestial phenomena was determined by the differences in the longitudes of the places of observation. The differences in the observed altitudes of known stars were due to the differences in the latitudes of the places of observation.[2] By taking the elevation, at zenith, of a known star and comparing that value with the one given in an ephemerides, prepared for a place of known latitude, the navigator could compute the latitude of his position. To compute the longitude by observing such a rare phenomenon as a lunar eclipse, required an accurate determination of local sun time. Such an able dead-reckoning navigator as Christopher Columbus (1451-1506) made only infrequent celestial observations to estimate his latitude. These estimates later proved to be as much as twenty degrees in error.[3]

Seventeenth century captains relied very heavily upon dead-reckoning navigation and the accuracy resulting varied with the skill of the navigator. To shipowners, such methods seemed haphazard. Serious errors could be extremely expensive. Governments and private individuals commissioned scholars to either improve existing methods of navigation or to invent new ones.[4]

Thomas Hariot (1560-1621), sponsored by Sir Walter Raleigh, found that those captains who did use celestial observations to ascertain their latitude, were frequently using tables of declination as much as one hundred years out of date. Hariot prepared new tables, making very minor corrections, for Raleigh's private use. Although Hariot's tables were compiled in 1608, English tables for general use did not appear until 1644. A Cambridge scholar, Edward Wright (1560-1615), in the pay of Lord Cumberland, sought to improve dead-reckoning by adapting the Mercator Map into the True Chart. After solving a complicated trigonometric problem, the navigator could plot his position on the new Wright-Mercator Map.[5]

Maurice of Orange commissioned Simon Stevin (1548-1620) to improve Dutch navigation. Stevin applied the magnetic variation theories of William Gilbert (1544-1603) and produced a theory by which, given a ship's latitude and the local variation of the magnetic compass from true north, the longitude could be computed. Unfortunately, while a good ship's compass was only accurate to one-half point or five and three-quarters degrees, isogonic lines of one degree variation were frequently over one hundred miles apart.[6]

Galileo Galilei (1564-1642) suggested that the occultations of the satellites of Jupiter might be useful in finding longitude.[7] This scheme required not only an accurate value for local sun time but also an astronomical telescope. Christian Huygens (1629-1695) attempted to his recently perfected pendulum clock to the solution of the longitude problem.[8] To find the meridian one needed only: an accurate chronometer, a line drawn on the floor of the ship, and that the ship be absolutely motionless while the observation was being made. It would seem, at first glance that the problem was one of communication. The navigators were not sufficiently educated in mathematics, the language of astronomy, to comprehend or appreciate the solutions offered them by the scientists. The scientists, on the other hand, seem to have had insufficient information concerning the problems they were asked to solve.

To improve the possibility of communication, Charles II of England instituted a school of mathematics at Christ's Hospital. Samuel Pepys (1633-1703), Secretary of the Admiralty in 1677, inaugurated an examination for naval lieutenants which included a section on mathematics.[9] William III commissioned an astronomer, Edmund Halley (1656-1742), to circumnavigate the globe in *HMS Paramour Pink*.[10]

Governments not only tried to improve communications between scientists and navigators but also added the incentive of financial rewards. In 1598, Philip III of Spain offered 1,000 Crowns to the man who solved the problem of determining longitude at sea. The Estates General of the Netherlands made an offer of 10,000 Florins at about the same time. Although these rewards rose to 10,000 Crowns and 100,000 Florins respectively, they went uncollected. In 1713, the English Parliament not only offered a reward but also financial assistance to anyone who presented a promising method for finding the longitude.[11]

In 1763, John Harrison (1693-1776), an English watchmaker, produced a chronometer sufficiently accurate for use in ascertaining the time difference in a star's position relative to the observer and the predicted position relative to an observatory of known longitude.[12] The cost of such an instrument was so high that even the Royal Navy could not make a general issue of the navigational chronometer until 1825.[13] The practical solution to the problem of finding one's position at sea was not the result of the creation of a new astronomical concept or the genius of a diligent navigator or even the efforts of a fine watchmaker. The practicability of modern celestial navigation depends upon relatively cheap, relatively accurate instruments, charts, and star tables, coupled with sufficient training on the part of the navigator. With this equipment he is able to make the observations and computations by which he may check his dead-reckoning. Modern navigation tables are constructed assuming a stationary spherical earth in the midst of a rotating sphere of fixed stars.

NOTES

[1]Samuel Eliot Morison, *Admiral of the Ocean Sea* (Boston: Little Brown and Company, 1952), pp 175-185.

[2]Claude Ptolemy, "The Almagest," *Great Books of the Western World*, ed. Robert Maynard Hutchens *et al.* (48 vols; Chicago: Encyclopaedia Britannica Inc., 1952),XVI, pp 7-9.

[3]Morison, *Admiral*, p 258.

[4]Maurice Ashley, *England in the Seventeenth Century* (London: Penguin Books, 1952), p 102.

[5]E. G. R. Taylor, *The Havenfinding Art* (New York: Abelard-Schuman, 1957), pp 215-228.

[6]Ernst Crone, *et al.* eds., *The Principal Works of Simon Stevin* (3 vols; Amsterdam: C. V. Swets and Zeitinger, 1961), I, pp 411-415.

[7]Galileo Galilei, "Proposte per la determinazione della longitudine," *Le opera di Galileo Galilei edizione nazionale sotto gli auspicii sua Magesta il Re D'Italia* (20 vols; Firenze: G. Barbera, 1890-1909), V, pp 413-425.

[8]Christian Huygens, "Instructions concerning the use of the pendulum-watches for finding the longitude at sea," *Philosophical Transactions: Giving Some Accompt of the Present Undertakings, Studies and Labors of the Ingenious in Many Considerable Parts of the World* (London: John Martyn, 1669), IV, #47, pp 937-953.

[9]R. H. Curtiss, "An Account of the Rise of Navigation," *Annual Report of the Board of Regents of the Smithsonian Institute—1918* (Washington: Government Printing Office, 1920), p 26.

[10]Eugene F. MacPike ed., *Correspondence and Papers of Edmund Halley* (London: Taylor and Francis, 1937), p. 226.

[11]Abott Payson Usher, *A History of Mechanical Inventions* (Cambridge: Harvard University Press, 1961), p 324.

[12]Charles Singer *et al.* eds., *A History of Technology* (4 vols; Oxford: Clarendon Press, 1957), III, p 672.

[13]Thomas Ford, "The Dawn of Navigation and its Books Theories and Instruments," *1906 Proceedings of the United States Naval Institute* Volume XXXXII (Annapolis: United States Naval Institute, 1906), p 274.