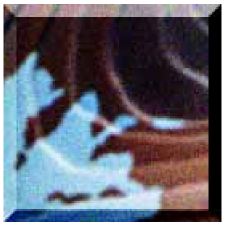

A Brief History of Early Navigation

Dava Sobel

In an age when a network of orbiting satellites can nail down a ship's—even a hiker's—position within a few feet in just a moment or two, it is sobering to remember the period when all the world's navies became hopelessly lost at sea the moment they lost sight of land. The precise determination of longitude, now available at the press of a button, once constituted a global dilemma that persisted for several centuries. Huge sums of money were offered by desperate heads of state to anyone who could devise a workable solution to the insuperable longitude problem.

For lack of a practical method of determining longitude, every great captain in the Age of Exploration had only a vague idea of where in the world he was, despite the best available charts and compasses. From Vasco da Gama to Sir Francis Drake, they all got where they were going willy-nilly, by forces attributed to good luck or the grace of God.

Renowned astronomers approached the longitude challenge by appealing to the clockwork universe: Galileo Galilei, Jean Dominique Cassini, Christian Huygens, Sir Isaac Newton, and Edmond Halley all entreated the Moon and stars for help. Palatial observatories were founded at Paris and London for the express purpose of determining longitude by the heavens. Meanwhile, lesser minds devised schemes that depended on the yelps of wounded dogs, or the cannon blasts of signal ships strategically anchored, somehow, on the open ocean.

In the course of their struggle to find longitude, scientists struck upon other discoveries that changed their view of the universe. These included the first accurate determinations of the distance to the stars and the speed of light.

As time passed and no method proved successful, the search for a solution to the longitude problem assumed legendary proportions, on a par with discovering the Fountain of Youth, the secret of perpetual motion, or the formula for transforming lead into gold.

Launched on a mix of bravery and greed, the sea captains of the fifteenth, sixteenth, and seventeenth centuries relied on "dead reckoning" to gauge their distance east or west of home port. The captain would throw a log overboard on a knotted cord and observe how quickly the ship receded from this temporary guidepost. He noted the crude speedometer reading in his ship's logbook, along with the direction of travel, which he took from the stars or a compass, and the length of time on a particular course, counted with a sandglass or a pocket watch. Factoring in the effects of ocean currents, fickle winds, and errors in judgment, he then determined his longitude. He routinely missed his mark, of course, searching in vain for the island where he had hoped to find fresh water, or even the continent that was his destination.

Long voyages waxed longer for lack of longitude, and the extra time at sea condemned sailors to the dread disease of scurvy. The oceangoing diet of the day, devoid of fresh fruits and vegetables, deprived them of vitamin C, and their bodies' connective tissue deteriorated as a result. Their blood vessels leaked, making the men look bruised all over, even in the absence of any injury. When they were injured, their wounds failed to heal. Their legs swelled. They suffered the pain of spontaneous hemorrhaging into their muscles and joints. Their gums bled, too, as their teeth loosened. They gasped for breath, struggled against debilitating weakness, and when the blood vessels around their brains ruptured, they died.

Beyond this potential for human suffering, the general ignorance of longitude wreaked economic havoc on the grandest scale. It confined seafaring vessels to a few narrow shipping lanes that promised safe passage. Forced to navigate by latitude alone, whaling ships, merchant ships, warships, and pirate ships all clustered along well-trafficked routes, where they fell easy prey to one another.

Spurred to action by a series of naval catastrophes, the British Parliament passed its famed Longitude Act in the summer of 1714, offering a prize of £20,000 (roughly $12 million in today's currency) for any device or technique that would enable mariners to find their exact longitude, give or take 30 nautical miles.

The Longitude Act established a blue ribbon panel of judges that became known as the Board of Longitude. It consisted of scientists, admirals, and government officials. According to the Longitude Act, the Board could give incentive awards to help impoverished inventors bring promising ideas to fruition. This power over purse strings made the Board of Longitude perhaps the world's first official research and development agency. (Though none could have foreseen it at the outset, the Board of Longitude was to remain in existence for more than 100 years. By the time it finally disbanded, in 1828, it had disbursed funds in excess of £100,000, even though the longitude prize itself was never paid off in full.)

In order for the commissioners of longitude to judge the actual accuracy of any proposal, the technique had to be tested on one of Her Majesty's ships, as it sailed "over the ocean, from Great Britain to any such Port in the West Indies as those Commissioners Choose . . . without losing their Longitude beyond the limits before mentioned."

So-called solutions to the longitude problem had been a dime a dozen even before the act went into effect. After 1714, with their potential value exponentially raised, such schemes proliferated. Over the course of its long history, the Board nearly collapsed under the weight of blueprints for perpetual motion machines and proposals that purported to square the circle or make sense of the value of pi—and never mind that these issues had nothing whatever to do with the problem at hand.

In the wake of the Longitude Act, the concept of "discovering the longitude" became a synonym for attempting the impossible. Longitude came up so commonly as a topic of conversation—and the butt of jokes—that it rooted itself in the literature of the age. In *Gulliver's Travels*, for example, the good Doctor Lemuel Gulliver, when asked to imagine himself as an immortal Struldbrugg, anticipates the enjoyment of witnessing the return of various comets, the lessening of mighty rivers into shallow brooks, and "the discovery of the longitude, the perpetual motion, the universal medicine, and many other great inventions brought to the utmost perfection."

The whole trick to solving the longitude problem lay in being able to keep accurate time aboard ship while simultaneously keeping track of the correct time at the port of origin. By comparing the local hour at sea with the precise hour back home, navigators could convert a time difference into a geographical separation. Since the Earth is a sphere, 360° in circumference, and takes a full day to make one revolution, then each hour's time difference between two locations equals 360 divided by 24, or 15° of longitude. The degrees, in turn, can be expressed as nautical miles with the help of some further calculations. At the equator, where the girth of the Earth is greatest, 15° of longitude stretch fully 1000 miles. North or south of that line, however, the mileage value of each degree decreases. One degree of longitude equals four minutes of time the world over, but in terms of distance, 1° shrinks from 68 miles at the equator to virtually nothing at the poles.

By the middle of the eighteenth century, the race for the longitude prize had come down to two contenders. On one side was the entire scientific establishment of Europe, wholeheartedly committed to using a complex system of celestial observations, called "lunar distances," to determine time in two places at once and thereby fix the longitude. On the other side, a lone, self-taught English clockmaker named John Harrison proposed a mechanical watch that would carry the true time at the home port to any remote corner of the world.

Harrison was an outsider and a dark horse. Even Newton, as the first Commissioner of Longitude, had opined strongly, on more than one occasion, that no watch or clock would ever rise to the challenge of keeping sufficiently accurate time aboard ship to be of use in determining the longitude. And yet, Harrison's invention eventually proved itself to be the superior method.

With no formal education or apprenticeship to any watchmaker, Harrison nevertheless constructed a series of virtually friction-free clocks that required no lubrication. He intentionally avoided the messy horological oils in use at that time because they changed their viscosity with every rise or fall in ambient temperature, thereby precipitating a change in the clock's rate. He also did away with the pendulum, which turned into a terrible liability on the deck of a rolling ship. He even circumvented the tendency of metals to expand when heated and contract when cooled, by combining different metals inside his works in such a way that when one component stretched or shrank, the other counteracted the change and kept the clock's rate constant.

A series of successful trials at sea and vociferous battles in Parliament eventually saw Harrison rewarded for his efforts—after 40 struggling years of political intrigue, international warfare, academic backbiting, scientific revolution, and economic upheaval. All these threads, and more, entwine in the lines of longitude.

When John Harrison died on 24 March 1776, exactly 83 years to the day after his birth in 1693, he held martyr status among clockmakers. For decades he had stood apart, virtually alone, as the only person in the world seriously pursuing a timekeeper solution to the longitude problem. Then suddenly, in the wake of Harrison's success, legions of watchmakers took up the special calling of marine timekeeping. It became a boom industry in a maritime nation. Indeed, some modern horologists claim that Harrison's work facilitated England's mastery over the oceans and thereby led to the creation of the British Empire, for it was by dint of the chronometer (or perfect timekeeper) that Britannia ruled the waves.

Captains of the East India Company and the Royal Navy flocked to the chronometer factories. Although naval officers had to pay for a chronometer out of their own pockets, most were pleased to make the purchase. Logbooks of the 1780s bear this out, for they begin to show daily references to longitude readings by timekeeper. In 1791, the East India Company issued new logbooks to the captains of its commercial vessels with preprinted pages that contained a special column for "longitude by Chronometer." Many navy captains continued to rely on lunars, when the skies allowed them to, but the chronometer's credibility grew and grew. In comparison tests, the first of which had been conducted by Captain James Cook on his second voyage of circumnavigation, chronometers proved themselves an order of magnitude more precise than lunars, primarily because they were simpler to use. The unwieldy lunar method, which demanded a series of astronomical observations, ephemerides consultations, and corrective computations, opened many doors through which error could enter.

By the turn of the century, the Royal Navy had procured a stock of chronometers for storage in Portsmouth, at the Naval Academy, where a captain could claim one as he prepared to sail from that port. With supply small and demand high, however, officers frequently found the academy's cupboard bare and continued to buy their own.

Independent producers sold chronometers at home and abroad for use on naval ships, merchant vessels, and even pleasure yachts. Thus, the total world census of marine timekeepers grew from just one in 1735, when Harrison completed his first design, to approximately 5000 instruments by 1815.

It was not uncommon for one ship to rely on two or even three chronometers, so that the timekeepers could keep tabs on each other. Big surveying ships might carry as many as 40 chronometers. Records show that when HMS *Beagle* set out in 1831, bent on fixing the longitudes of foreign lands, she had 22 chronometers along to do the job. Half of these had been supplied by the Admiralty, whereas six belonged personally to Captain Robert Fitzroy, who had the remaining five on loan. This same long voyage of the *Beagle* introduced its official naturalist, the young Charles Darwin, to the wildlife of the Galápagos Islands.

In 1860, when the Royal Navy counted fewer than 200 ships on all seven seas, it owned close to 800 chronometers. Clearly, this was an idea whose time had come. The infinite practicality of John Harrison's approach had been demonstrated so thoroughly that its once formidable competition simply disappeared. Having established itself securely aboard ship, the chronometer was soon taken for granted, like any other essential thing, and the whole question of its contentious history, along with the name of its original inventor, dropped from the consciousness of the seamen who used it every day.

THE AUTHOR

DAVA SOBEL, an award-winning former science reporter for *The New York Times*, is the author of *Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time* (Walker, 1995; Penguin, 1996). Her articles about astronomy have appeared in *Audubon*, *Discover*, *Life*, *Omni*, and *The New Yorker*. She is currently at work on a book about Galileo. *Longitude*, which has been translated into 20 foreign languages including Hebrew and Icelandic, won the 1996 Book of the Year Award in England, the Prix du Faubert de Coton in France, and the Premio del Mare Circeo in Italy. Her e-mail address is dsobel@i-2000.com.

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