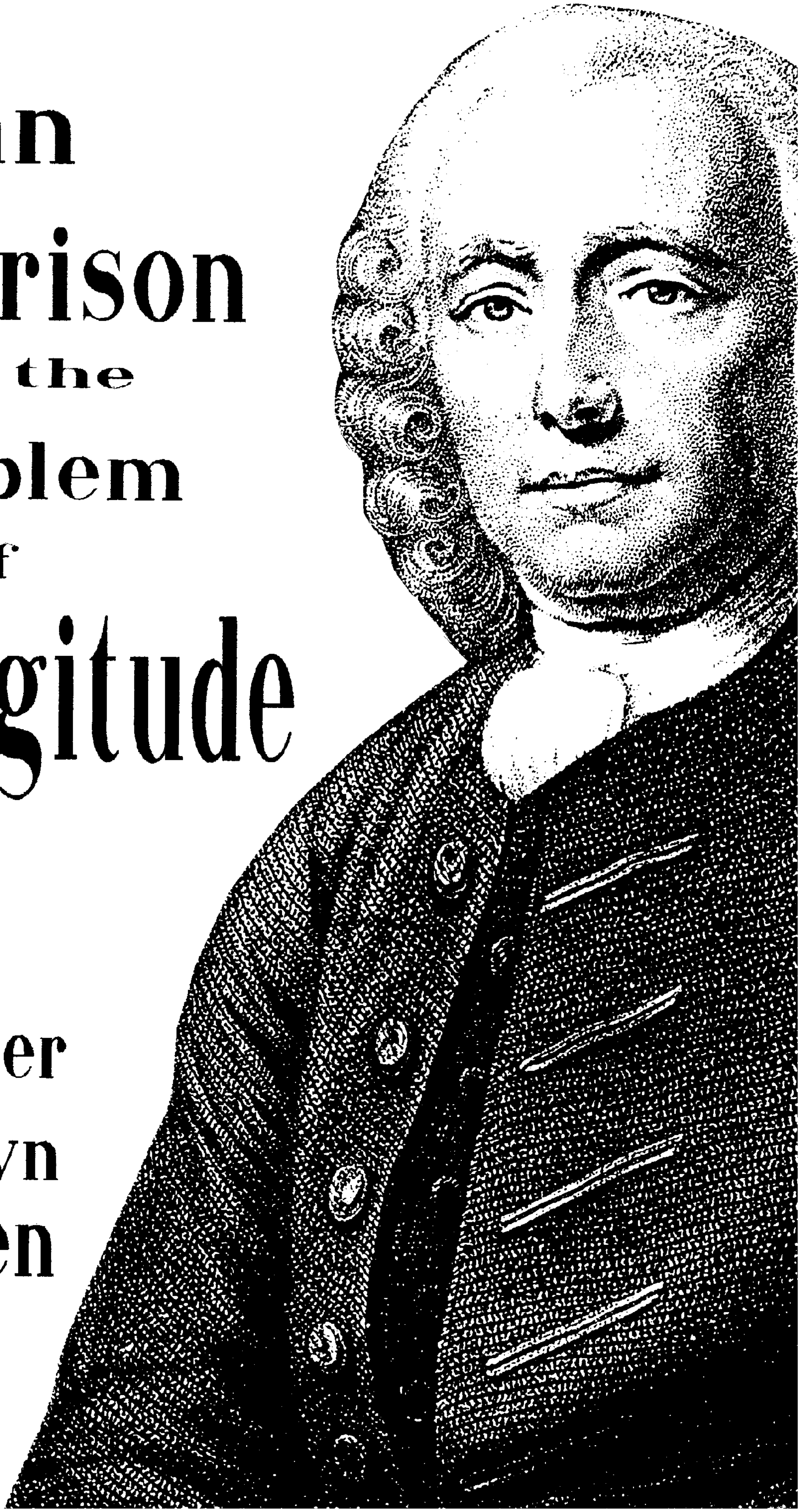
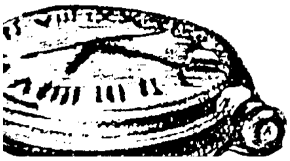
John Harrison and the Problem of Longitude

Heather and Mervyn Hobden





Illustrations from out-of-copyright sources, or fully attributed.

The Cosmic Elk

http://www.cosmicelk.net

First published in 1988
Second edition 1989
Third edition 1990
Fourth edition 1993
Fifth edition 1995
Sixth edition 1998
Seventh edition 1999
Updated 2009.
New edition: 2013

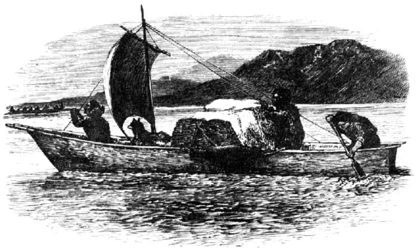
British Library Cataloguing-in-Publication Data.
A catalogue record for this book is available from the British Library

ISBN -13: 9781871443165

John Harrison and the Problem of Longitude

by Heather and Mervyn Hobden

The problem of longitude and how John Harrison solved it.



Finding the Direction

The earliest navigators we know of who encountered the problem of finding their ship's position in open featureless ocean were the first Australians. There is archaeological evidence that enough people were settled in Australia 65,000 years ago, to have a marked effect on the extinction of the larger animals. Ancestors of many of them may have arrived 150,000 years ago or much earlier, even possibly as much as 700,000 years ago. Even during an ice-age, when the level of the sea was lower than today, the Australian continent was separated from the islands of Indonesia, by open sea wide enough to present a barrier to plants and animals.

This sea, with its strong currents, inhabited by crocodiles, sharks and jellyfish, could only have been crossed by people in well made boats who knew how to find their way safely to another shore. The others would not have made it.

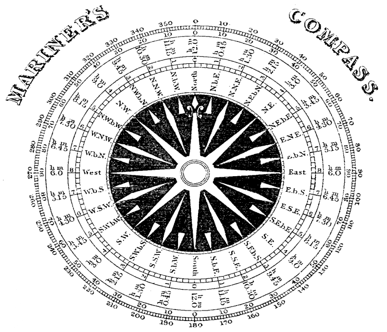
These early navigators were already accustomed to sailing between islands – some Indonesian islands have been inhabited by human ancestors for a million years, and the earliest hominid finds on Java date to two million years ago.

Some traditional methods of navigation may have been in use for many thousands of years. Navigation requires skilled knowledge, which has to be taught, it can not just be learned only by personal experience. When you went to sea, you had to know how to find out where you were, or you might not survive. Navigators learnt how to find indications of their position and direction from the position of the sun, from the direction of the winds, from the shape and direction of waves, from the changing colours and taste of the sea and the currents seen below the surface, from the appearance of clouds, from the behaviour of birds which return to land to roost on cliffs at night. And at night, the position of certain bright stars.

The direction in which the sun could be seen, indicated not only the direction you were facing, and also the time of day, but was associated with many other qualities. Neanderthal burials show that a belief in the significance of the direction of the sun was part of ritual and everyday life around 70,000 years ago. We can tell this, for many of the associations with the direction of the sun have remained in our beliefs and customs up to the present day.

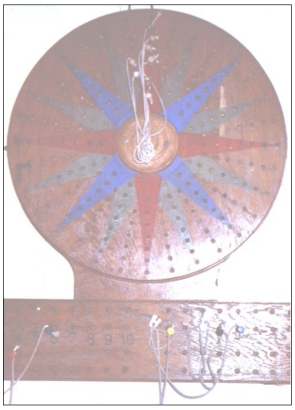
The direction of the rising sun, the east, was associated with life and good things. Our word "orientation" is derived from a word meaning "east". This, being the most auspicious, was the preferred direction. The "front". Buildings often faced this way or to the southeast or south to the rising or risen sun. Conversely, the direction of the setting sun and the dark north were associated with bad things and death.

In early beliefs everything in the universe was possessed by sentient spirits, beings or gods - so the directions of time and space were prayed to and offered sacrifices. The divisions of time or hours were named after the position of the sun, or after the deity that controlled that hour. There were always more divisions of time in early morning, this was the time of day most important to early navigators, and they learned how to tell from the appearance of the sky at dawn what the weather would be like in the coming day.



The magnetic compass was originally invented in China more than 2,000 years ago as a divining instrument to show the significant directional influences. It was soon found to be an invaluable navigational aid. The directions on mediaeval compasses from the Mediterranean were named after winds, and compasses still indicated the hours in the 19th century.

In the 16th to 19th centuries the ship's speed was found by using a 'log' thrown overboard, attached to a line 42 feet long knotted at fixed intervals paid out freely for 30 seconds, measured by a sand-glass and hauled in. The number of knots counted gave the speed in nautical miles per hour.



The compass gave the direction, and this was plotted on a traverse board, by a peg attached by string, which fitted into holes, and could be used by an illiterate sailor. The traverse board in the picture is a replica of the one used by John Cabot on the “Matthew” when he discovered Newfoundland.

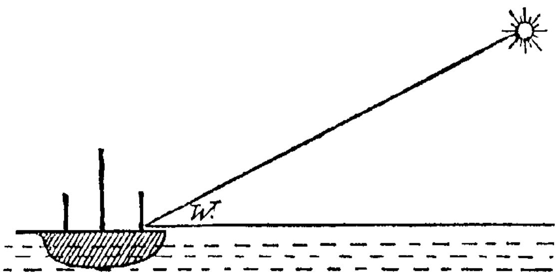
The accuracy of the method depended on the log remaining stationary as the ship sailed on, paying out the line. If the ship suddenly surged forward, then either the log was dragged through the water, or an excessive amount of line was dragged from the reel. Currents acting across the path of the ship created unseen errors. Also, the log could be swallowed by a fish.

At night, if the sky was clear, the best way of telling time and position was from the position of certain bright stars. To do this, you must know the appearance of the night sky very well, right through the year. Star maps and almanacs are needed as an aid to memory. The use of these can be dated back thousands of years.

Star maps and almanacs take time and careful effort to prepare, and need specialist knowledge. The first astronomers were the shamans, since the position of the heavenly bodies though the year helped the shaman to compile the calendar and know when to begin the seasons for hunting, fishing and so on, with the correct rituals to appease the supernatural beings which controlled such enterprises.

When astronomy became a more specialised profession, the astronomers were still also the priests, who not only compiled calendars and almanacs to ensure that rituals were carried out at the correct time of the year, but interpreted the meaning of events in the heavens for people on Earth, since they believed that events in the heavens predicted or controlled all affairs on Earth. No one would embark on any enterprise without first consulting the astronomer-priests, who thus exercised immense power over all the other members of society.

Finding the Latitude



—Measuring the Altitude of the Sun on Board Ship.
The angle w marks the sun's height above the horizon.

Although belief in a flat earth has persisted to the present, by about 2,000 years ago, Greek and Chinese astronomers had been able to calculate that the world was round. They knew that as one moved from the north, south towards the equator, the sun rose higher in the sky, and the north celestial pole around which the northern stars appeared to rotate night after night and in the course of the year, became lower - until on the equator, the sun was overhead and the north pole on the horizon.

This is measured in degrees, from the equator 0 degrees to the North Pole, 90 degrees. If we imagine drawing a line through the Earth from pole to pole, and from this a line across the plane of the equator, then measure the angle to any point on the Earth's surface, we have the **latitude** of this point. Finding the **latitude** at sea, then, is not too difficult. But to know our position we need at least two coordinates.

Longitude and Time

Finding our longitude – our distance east or west, is much harder. Where do we fix our position? The stars are the same right round the Earth at the same latitude. People watching the night sky in New York, will see the same stars above the horizon as observers in Madrid, Samarkand and Beijing. They are all at about latitude 40 degrees North.

The difference lies in the **time** they will be able to observe the same night sky. If you in England decide to phone someone in America one morning – they are likely to be in bed – their day has not yet began, and if you then phone someone in Australia – their day will be nearly over, it will be evening. Knowing your local time relative to the time in another place has been important long before rapid communications. It was astronomers, navigators and mapmakers who needed to know this. If you know your local time, and the local time in a place at a known distance east or west, you have a baseline, from which you can calculate your position on the Earth's surface, and many other things as we shall see.

To determine the time round the Earth, imaginary lines have drawn across the Earth from pole to pole at 15 degree intervals. This is the distance the sun appears to travel in one hour, and the lines are called meridians of longitude. To fix them, you need a prime meridian to start with, and this has to be determined by astronomical methods. China was mapped using a meridian calculated by astronomers in the 14th century. The prime meridian, 0 degrees, we use today, passes through the old Greenwich observatory, where it was calculated, and through Chingford and Louth. Each meridian passes through the centre of a time zone of one hour. They are counted from the **Greenwich meridian** which is Greenwich Mean Time, (GMT) - east we add an hour and west we lose an hour, until we reach the opposite side of the world.

The meridian of 180 degrees on the opposite side of the Earth, is called the **International Date Line** because when we cross it we cross into another day. This meridian is not a straight line but deviates round instead through, Chukotka, and groups of Pacific islands it would otherwise pass through, to avoid having two dates at the same time in the same country. Time zones do not always coincide with the hourly meridians, but are taken for convenience round country or regional boundaries.

Some countries are too big to have only one time zone, Australia, for example, the USA, and Russia which has eleven time zones. Many places do not have the time zones exactly according to their hourly meridian. The most usual change is one hour forward in summer.

Meridians have been used for centuries to find the longitude of other places relative to the fixed meridian, but each country used its own meridian as determined by its own local observatories or another of choice, as a reference, and many sailors made use of at least three different fixed meridians on the same charts.

The international system of time based on the Royal Greenwich Observatory, was set up in 1884 at a congress in Washington, although it was not until 1911 that France accepted the prime meridian through Greenwich not Paris. The Paris meridian had been calculated in the 17th century, using the times of the eclipses of the moons of Jupiter, and was used to map France – more about this later.

This international system of meridians of longitude and time, would have been of little use in navigation, unless the ships possessed some way of telling the time precisely while at sea.

The Use of Clocks

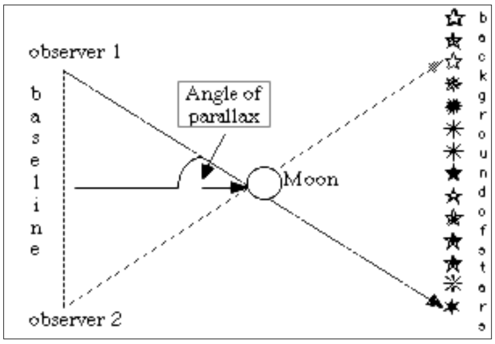
Mechanical clocks have been made for more than 2,000 years. They were powered by water until, in the 13th century, clocks powered by weights were made. But clocks driven by waterwheels and weights, however accurately they could be made were useless on the rolling seas. By the beginning of the 16th century, clocks were being made with the movement driven by a spring. These clocks could be portable, so they could be made very small and carried about on the person. These small portable clocks came to be known as watches. From the mid 16th century onwards, watches were carried by navigators as part of their kit. The method used is described in "The Cosmographical Glasse" by W. Cuningham, published in 1559:

You shall prepare a parfait clocke artificially made, such as are brought from Flaunders, & we have them as excellently without Temple barre, made of our countrymen.... When as you travel, you shall set the nedle of youre Diall exactlye on the hour found out by the sonne on the day & by some starre in the night; then travelling withoute intermission, whan as you have traveled xx yea, xl. miles or more (if your next place, whose longitude you desire be so far distant) then marke in your Diall, the houre that it sheweth; after with an astrolabe, or Quadrant, finde out the hour of the day in that place; & if it agre with the same which your clock sheweth, be assured your place is north or South from the place you came from, & therefore have the same longitude, & meridian line. But & the time differ, subtract th'one, out of th'other, & the difference turn into degrees & minut. of th'equinoctiall as before, then adde or subtract, as in th'other, & the other. ij. precepts, going before.

However the watches could not be made reliable enough to be very useful to the navigator who had to correct his watch at least once a day by reference to astronomical observations. The going rate of the navigator's watch was affected by the humidity and temperature changes, and even a slight inaccuracy in the time could be very serious. The nearer the equator you were, the worse the error. An error of 15 minutes in one day on your watch, which was not unusual, could mean an error of 240 miles in your estimated position!

With the invention and application of the telescope to astronomical use by the beginning of the 17th century, new methods were available for finding longitude.

Finding the Longitude by the Parallax of the Moon



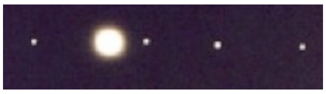
Since the Moon is very much nearer to us than the stars, its position with regard to a particular star is seen differently at the same time in places some distance apart. This "lunar parallax" measured accurately could be used in finding longitude. One method was to compare observations made in different places of the occultation of a particular star by the Moon.

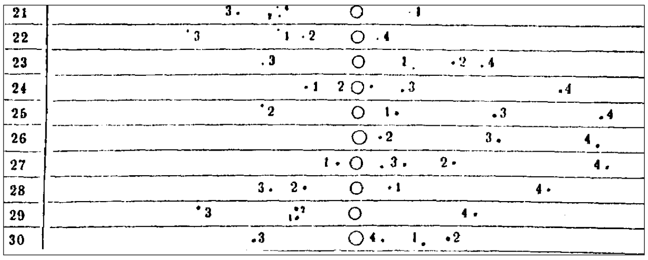
Finding the Longitude by an Eclipse of the Moon

Longitude could be calculated by comparing the times of the beginning or ending of an eclipse of the Moon, and then comparing this data with the times recorded by observations made on the same eclipse at different places on the Earth. One disadvantage of this method was that eclipses of the Moon can only be seen once or twice a year, although the date and time of eclipses could be predicted fairly accurately by the 17th century. Another problem was that the Moon had to be adequately mapped, so the position of the shadow could be measured accurately.

This method was used to determine the longitude of important ports and cities in the 17th and 18th centuries, and better and better maps of the Moon were published. There were obvious difficulties when it was tried using small telescopes on the deck of a boat at sea.

Finding the Longitude with the Eclipses of Jupiter's Moons





When Galileo observed the four largest moons of Jupiter through his telescope, in 1610, and saw how quickly they orbited round Jupiter he thought the timing of their eclipses could be used to determine longitude. Tables were made predicting the eclipses.

The method was useful in determining longitude on land. Bradley used this method to fix the longitudes of Lisbon and New York. At sea, though, there was a major problem. The moons of Jupiter can only be seen through a telescope, and trying to hold and focus a telescope on Jupiter, on the deck of a boat bobbing about on the sea was. of course, impossible. This did not prevent attempts to use this method at sea from the 17th to the 19th century. The use of this method at sea is described in **The New Practical Navigator** by John Hamilton Moore from the beginning of the 19th century to the early 20th century.

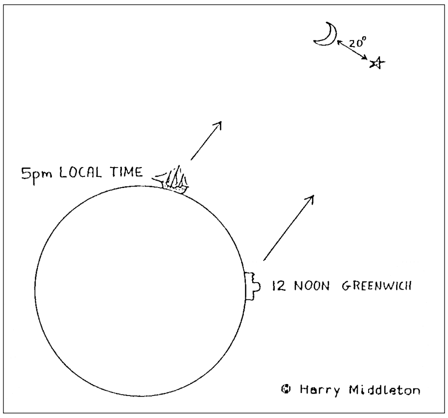
To find the Longitude by the Eclipses of Jupiter's Satellites.

On the day preceding the evening on which it is proposed to observe an eclipse, look for the time when it will happen at Greenwich, in page 3d of the month in the Ephemeris. Find the diff. of longitude either by a good map, sea chart, or dead reckoning.

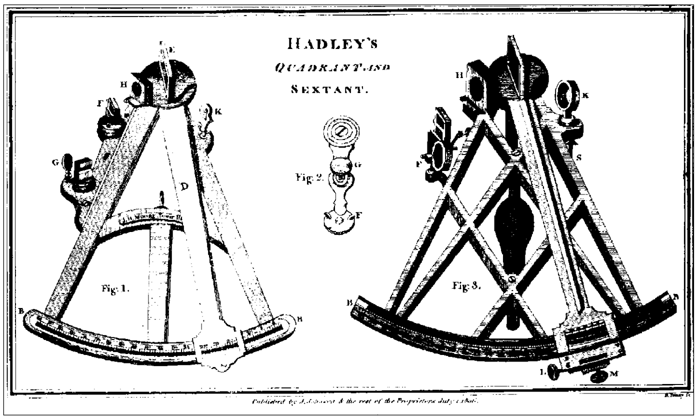
Let the watch be regulated by the sun with all possible exactness to the apparent time. Turn the difference of longitude into time, and add it to, or subtract it from, the apparent time, according as it is east or west of Greenwich, the sum or difference will be nearly the time when the eclipse is to be looked for in that place. But as the longitude is uncertain, it will be proper to begin 20 or 30 minutes before.

Observe the hours, minutes, and seconds of the beginning of the eclipse, called immersion, that is, the very instant that the satellite appears to enter into the shadow of Jupiter ; or the emersion, that is, when it appears to come out of the same. The difference of time between the observed immersion, or emersion, and that set down in the Nautical Almanack, being turned into degrees, will give the difference of longitude between Greenwich and the place of observation.

The Lunar Distance Method of Finding Longitude



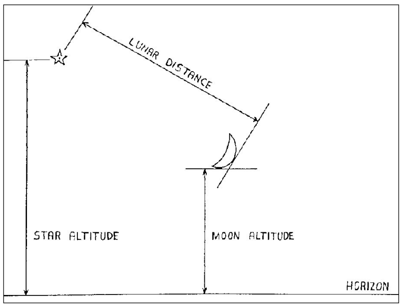
Another method used to find longitude, was to measure the angle between the moon and a star and to work out the longitude by referring to an almanac.
The angle continually changes as the moon appears to move across the sky relative to the stars, so each angle represents a particular moment of time. This is called the lunar distance method. It was suggested by Johann Werner in 1514 but the idea had been around for a long time. The only problem was the accuracy of the measurements.



During the 18th century, John Hadley's octant, quadrant and the development of the sextant, gave more accurate measurements of the angular distances.

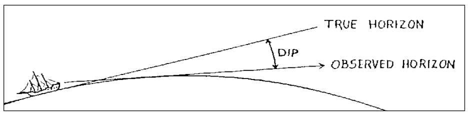
This method also needed accurate lunar tables and these were provided in the Nautical Almanac first published by Nevil Maskelyne.

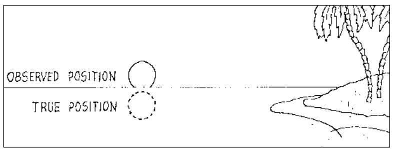
To use the lunar distance method of finding longitude at sea, the ship's officer well laden with the Nautical Almanac and his instruments, on the dark deck at night, first had to calculate local time from the altitude above the horizon of a particular star.



Then he observed the lunar distance by measuring the angular distance between the moon and this star, then measuring the altitude of the moon and the altitude of that star.

Then he had to calculate the allowance (called dip) for his height above sea level which made the observed horizon lower than the true horizon for his latitude.





And allow for refraction, the light from the moon entering the atmosphere at an angle is refracted, the nearer the moon to the horizon, the greater the refraction. At the horizon this is about 35 degrees, and the moon appears higher in the sky than it is.

Then he had to find the Greenwich time of the "cleared" lunar distance by referring to the tables in the Nautical almanac. And finally he obtained his longitude by comparing the local time of his observation with that of the predicted Greenwich time.

Because small observational errors were easily made, several observations of lunar distance were made one after another by different officers, and the mean of the observational results was used for the calculation of the longitude.Direction of the Earth's Magnetic Field

Diagrams on this page by Harry Middleton

Direction of the Earth's Magnetic Field

Variations in the direction of the compass needle had been known since the 16th century. In 1699-1700, Halley made the first isogonic chart showing lines of equal magnetic variation. From his observations of True North, made from sights taken of stars, he was able to establish the amount by which the compass varied. These charts made the compass more reliable as an indicator of direction. Halley had suggested they could be used to find the ships position. This was one of the methods proposed by Whiston and Ditton. It was soon found that the Earth's magnetic field was constantly changing, so after a few years the charts needed updating.

1660 Royal Society (http://www.royalsoc.ac.uk/)

founded by King Charles II under pressure to promote what was then called natural knowledge or natural philosophy - what we now call science.

Its members met weekly to conduct experiments and discuss scientific topics.It became a model for local societies throughout the country. Papers and letters were collected in weekly or monthly journals and regular lecture meetings were held.

1666 -Académie des Sciences Paris (http://www.academie-sciences.fr/)

The Academy was founded in Paris in 1666 by Jean-Baptiste Colbert. He was at that time controller general of finance in France and his programme of economic reconstruction was largely responsible for making France the leading power in Europe. Colbert was in a position to give the new Academy the support it needed and he arranged for it to meet in the royal library.

Christiaan Huygens

inventor of the pendulum clock, was one of the founder members of the Académie des Sciences. Granted a large pension and an apartment in its building. The pendulum became an important scientific tool, not only for timing but used in calculating the shape of the Earth. As a Protestant, Huygens was forced to return home to Holland permanently after the Revocation of the Treaty of Nantes by King Louis XIV in 1688 – which prevented freedom of religion.

1665 Paris Observatory

(http://www.obspm.fr/)

Architect Claude Perrault. Built without wood – to avoid fire – and without metal – to avoid magnetic disturbance. On the summer solstice of 1667 its exact orientation north – south was marked by members of the Académie Royale.

Its foundations go down to bedrock and its vaults below (where the standard metre is now stored) connect with the catacombs.

In its grounds and on its roof were massively long telescopes. Jean Picard (1620-1682) working in Paris, introduced the concept of using telescopic sights (with micrometer) as an essential part of all observing equipment.

It was Picard who suggested to King Louis XIV that Italian astronomer Giovanni Domenico Cassini (1625-1712), who was Professor of Astronomy at the University of Bologna) be invited to Paris as Director of the new Paris Observatory, which was completed in 1671. Four generations of Cassinis acted as Director until the Revolution.

Olé (Olaus) Christensen Römer

Picard's main concern was measuring the Earth, and the length of a meridian – which was essential for accurate mapping and navigation.

To help determine the meridian of the new Paris Observatory, Picard travelled to Denmark, to check the exact position of Tycho Brahe's old Observatory. He was helped by Danish astronomer Olé Römer, whom he invited to Paris.

Römer was invited to work at the Paris Observatory. Like Huygens and many others, Römer had to leave France after the Revocation of the Treaty of Nantes.

Measuring Distances on Earth

One of the main methods to determine the Paris meridian of longitude was by the observation of the eclipses of Jupiter's satellites, as suggested by Galileo, who was awarded a gold chain as a prize.

When they started mapping France using the new data, it turned out to be much smaller than on earlier maps – causing King Louis XIV to complain that his astronomers had lost him more territory than his generals.

Horologii Oscillatorii

In 1673, the Dutch physicist Christiaan Huygens published a landmark treatise on the measurement of time.

In this he described the first clock using a pendulum to control the stability of oscillation, which he had invented in 1656.

He went on to describe a pendulum clock mounted in gimbals to find the Longitude at sea. Furthermore, Huygen’s design was backed up using mathematics, synthetic geometry to qualify his reasoning.

Holland, as a major seafaring nation, had great need of a solution for the longitude problem. This invention had a dramatic effect on the practical technology of the time, by 1657, Fromanteel was selling pendulum clocks in London.

The sea clock was a failure, it performed well in a flat calm, but was useless in any seaway. It also varied too much with temperature, some form of compensation was required.

Numerous attempts were made by other inventors, such as Robert Hooke, to overcome these problems, mainly by the substitution of a balance spring controlled balance.

1675: The Royal Greenwich Observatory

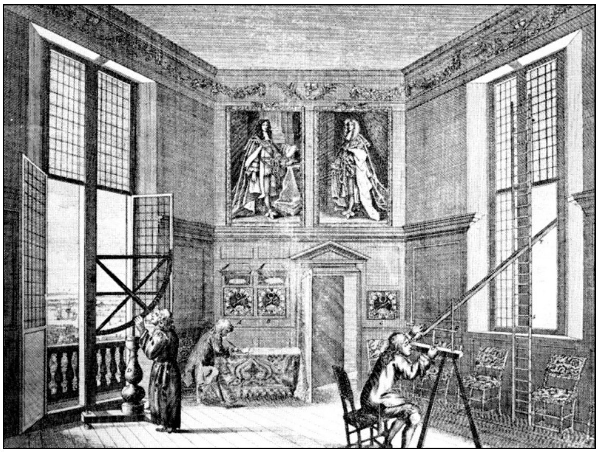
http://www.rog.nmm.ac.uk/

The RGO was founded in 1675 by decree of Charles II. He had been pressured to do so, since there already an observatory in Paris, by a number of people including his French mistress Louise de Keroualle.

The first Astronomer Royal, John Flamsteed, (born 1646 in Derbyshire), was charged "to apply himself with the most exact care and diligence to the rectifying of the tables of the motions of the heavens, and the places of the fixed stars, so as to find out the so much desired longitude of places for the perfecting the art of navigation."

The site chosen was on the remains of a 15th century tower on a crumbling hill in the grounds of Greenwich Palace, no longer occupied by the King. This was the remains of the original castle, replaed by Greenwich Palace by Henry VII and last used by Henry VIII to accomodate his current mistress nearby.

Sir Christopher Wren – not just a famous architect but Savilian Professor of Astronomy at Oxford University, was called in to design the building.



The plan incorporated a magnificent Octagon Room above the astronomer's ground floor flat, with three Tompion clocks built in. This was supposed to be the main observatory. A picture shows astronomers with telescopes at the windows in broad daylight. And a transit quadrant perched by a little balcony. In fact this room was useless for observing transits, as, unlike the Paris Observatory, the building had not been correctly aligned. To save costs, the new observatory was built over the crumbling foundations of the old tower. Not a good idea.

In observatories the transit instrument – needed to compile the tables – the main purpose of the 18^{th} century observatory, is not only precisely aligned north-south it is firmly fixed in solid ground to avoid any movement. The foundations of the Paris observatory went down to the bed rock.

Flamsteed had to build a wall in a garden shed with the correct alignment, on which he could fix a 7-foot quadrant with telescopic sights to measure and record the position of the stars as they passed the north-south meridian.

Flamsteed invested £120 of his inheritance when his father died on a new 10-foot quadrant designed by Robert Hooke, but complained that it trapped his fingers.

Flamsteed had to buy most of the equipment and furniture he needed. His stingy and rarely paid salary meant he had to take on paying students to make ends meet, one of these was Edmund Halley, who was to become his successor as Astronomer Royal. Flamsteed's wife Margaret who he married when he was aged 46, was one of the assistant astronomers.

Flamsteed was reluctant to publish his star tables before he felt the work was complete. But in 1704, Queen Anne's husband, Prince George of Denmark, (yes that is he on a much larger painting at Hampton Court), who as Lord Admiral was interested in astronomy and the problem of longitude, and advised by Newton, undertook the cost of publication. Despite the prince's death in 1708 and Flamsteed's objections, 400 copies were printed in 1712, prepared for the press by Edmond Halley.

Flamsteed was furious at the pirating of his work, calling Halley "a malicious thief" and taking legal action. He won his case and was able to get 300 of the 400 copies already printed destroyed.

After Flamsteed's death in 1719, his wife Margaret took all the instruments, furnishing and papers, (which were hers anyway) and with Flamsteed's assistant astronomer, Abraham Sharp, finished and published his tables in 1725.

Called the Historia Coelestis Britannica, it listed more stars - 3,000 - than previous tables - and gave their positions much more accurately.

Flamsteed's successor Edmund Halley, found he had inherited an empty building. Halley insisted that the observatory should be equipped by a Royal grant. Halley included among his many scientific interests the problems of navigation.

Edmund Halley, was perhaps the first astronomer to realise the importance of the history of the science. Looking back through ancient records of eclipses, Halley discovered that the Moon was apparently accelerating over the years. We now know that in fact the friction of the tides is slowing the Earth’s rotation down.

The Astronomer Royal was provided with a job and a house with it, for life. Halley's attempt to resign because of his advanced age, in favour of James Bradley was turned down. Bradley became the Astronomer Royal when Halley died in 1742.

It was Halley that was to provide Harrison with initial support and encouragement that enabled him to devote his life to making a clock for finding the time at sea. Bradley, as we shall see, was to compete for the longitude prize himself, with the astronomical lunar distance method of finding longitude.

Whiston and Ditton

In 1713, two English scientists came up with a solution to the problem of finding longitude at sea. The Rev. Humfrey Ditton was a mathematics master at Christ's Hospital School. The Rev. William Whiston (pictured) had been Isaac Newton's successor as Lucasian Professor of Mathematics at Cambridge. He is called "wicked" in the song below because he was sacked from his position for his "heretical "views. In his books, he had suggested natural causes for the Earth's origins, and that Noah's Flood in the Bible, might have been caused by a comet passing near the Earth, and was one of a number of naturally caused catastrophes.

The two ancient English universities Oxford and Cambridge, were at this time, mainly concerned with turning out Church of England clergymen. To get a degree you also had to be ordained. (Edmund Halley had not finished his degree for this reason, and later the Archbishop of Canterbury tried to prevent him becoming appointed Savillian Professor of Mathematics at Oxford. He too, had tried to calculate the age and origin of the Earth by scientific means).

This is why John Harrison speaks (with contempt) of "Oxford and Cambridge education" and "priests and scholars". Scientific progress in the 18th century in England did not come from its universities.

So however good Whiston and Ditton's idea for finding longitude at sea was, it would never be acceptable, as they had fallen foul of the establishment. Their idea proposed that light-ships be anchored in certain positions along the main ocean routes. At midnight precisely, these ships would fire a shell to a height of 6,440 feet. This, according to the authors' calculations would enable the spark and explosion to be seen and heard a distance of 85 miles, and thus provide a method by which the time aboard ships could be corrected and the position checked.

Whiston and Ditton published details of their scheme in "The Guardian" of 14th July 1713, and "The Englishman" of 10th December 1713. In 1714, they brought out a book called "A New Method For Discovering The Longitude".

The basic principle of their idea - that a ship could fix its position from time signals - was excellent. When the technology to make it feasible become available in the 20th century it did come to be the established method, first with radio time signals, then satellite navigation. Whiston and Ditton's idea was very popular with the general public who felt it was about time the government invested some funds and effort into preventing the appalling losses of ships, cargo, passengers and crew. But the establishment did not like Whiston and Ditton and ridiculed their schemes. Ditton died, disappointed, in 1715. After the death of Queen Anne, the heresy charge against Whiston was dropped.

A rude song was published about Whiston and Ditton called:

Ode, for Musick. On the Longitude

The Longitude mist on
    By wicked Will Whiston
And not better hit on
    By good Master Ditton.

So Ditton and Whiston
    May both be bep-st on;
And Whiston and Ditton
    May both be besh-t on.

Sing Ditton,
    Besh-t on;
And Whiston
    Bep-st on.

Sing Ditton and Whiston,
    And Whiston and Ditton,
Besh-t and Bep-st on,
    Bep-st and Besh-t on.

John Harrison knew this song well, for he applied its sentiments to his own comments about the members of the Board of Longitude, in his book, written many years later.

The publicity given to Whiston and Ditton had brought to public attention the lack of progress in finding a solution to the longitude problem, the need for someone to pressure for government action. They suceeded in getting a bill passed in Parliament:

"Towards the latter End of April, Mr. William Whiston, M.A. and Mr. Humphry Ditton, Master of the New Mathematical School in Christ's Hospital, London, having as they thought, found a new Method, for discovering the Longitude both at Land and Sea, were encouraged by some Gentlemen to apply themselves to the House of Commons for a Reward, which they did in the following Paper, or Petition.

Petition of Mr. Whiston and Mr. Ditton, for a Reward for Discovery of the Longitude.

'Whereas her Majesty has been pleased, this very Sessions of Parliament, particularly to recommend the Improvement of the Trade and naval Force of Great Britain, from the Throne: And whereas it is known, that nothing can be either at home or abroad, more for the common Benefit of Trade and Navigation, than the Discovery of the Longitude at Sea which has been so long desired in vain, and for want of which so many Ships and Men have been lost: Whereas also a Proposal for that Purpose has now been offered to the World for some Time, and has met with Approbation among some of the best Judges, to whom it has been privately discovered, but, for Want of any suitable Encouragement, could not hitherto be communicated to the Public: It is humbly desired, that a Bill, or Clause of a Bill, may be brought in this Parliament, to appoint a suitable Reward, for such as shall first lay before the Public, any sure Method for the Discovery of that Longitude; to be then due, when the most proper Judges, who may be appointed in the Bill, shall declare that such Method is both true in it self, and is also practicable at Sea; That the lowest Reward may be allotted to the discovering the same within one whole Degree of a great Circle, or seventy measured Miles; a greater to the discovering it within one half; and a still greater to the discovering it within one Quarter of that Measure: And that withal, if it be thought fit, proper Rewards may be also allotted to such as shall afterward make any farther considerable Improvements for the perfecting so important a Discovery. This is the humble Desire of the Authors of this Invention, as well as of many others; who are unwilling that this their Native Country of Great Britain should lose the Honour and Advantage of its first Discovery, Practices and Encouragement.' April 29, 1714.

Resolutions of the Committee thereupon.

The House appointed a Committee, to consider what Encouragement was fit to give to such as should find out the Longitude; which Committee, having on the 4th of June, asked Mr. Whiston and Mr. Ditton some Questions, in the Presence of Sir Isaac Newton, Dr. Halley, and some other celebrated Mathematicians, came to these two Resolutions,

1. 'That it is the Opinion of this Committee, that a Reward be settled by Parliament, upon such Person or Persons, as shall discover a more certain and practicable Method of ascertaining the Longitude, than any yet in Practice, and that the said Reward be proportioned to the Degree of Exactness to which the said Method shall reach.'
2. That the House be moved, that Leave be given for a Bill to be brought in accordingly.

On the 25th May 1714, a petition was delivered to Parliament by "Captains of Her Majesty's ships, Merchants of London, and commanders of Merchant-Men" demanding that research into solving the problem of finding the longitude be encouraged by offering a substantial award.

In June 1714, a special parliamentary committee was set up to investigate the longitude problem. They recommended:

"That a reward be settled by Parliament upon such Person or Persons as shall discover a more certain and practicable method of ascertaining the Longitude than any yet in practice.

The committee had said:

"The House proceeded to take into Consideration the Report from the Committee, who were to consider of what Encouragement was fit to be given to such as should find out the Longitude at Sea.

That it appeared to the said Committee as followeth; viz.

Mr. Ditton and Mr. Whiston, being examined, did inform the Committee, That they had made a Discovery of the Longitude; and were very certain, that the same was true in the Theory; and did not but doubt that, upon due trial made, it would prove certain and practicable at Sea.

That they had communicated the whole History of their Proceedings towards the said Discovery to Sir Isaac Newton, Dr. Clark, Mr. Haley, and Mr. Cotes; who all seemed to allow of the Truth of the Proposition, as to the Theory: but doubted of several Difficulties that would arise in the Practice.

Sir Isaac Newton, attending the Committee, said That for determining the Longitude at Sea, there have been several Projects, true in the Theory, but difficult to execute:

- One is, by a Watch to keep Time exactly: But, by reason of the Motion of a Ship, the Variation of Heat and Cold, Wet and Dry, and the difference of Gravity in different Latitudes, such a Watch hath not yet been made:
- Another is, by the Eclipses of Jupiter's Satellites: But, by reason of the Length of Telescopes requisite to observe them, and the motion of a Ship at Sea, those Eclipses cannot yet be there observed.
- Another is, by the Place of the Moon: But her Theory is not yet exact enough for this Purpose; It is exact enough to determine her Longitude within Two or Three Degrees, but not within a Degree:
- A Fourth is, Mr. Ditton's Project: And this is rather for keeping an Account of the Longitude at Sea, than for finding it, if at any time it should be lost, as it may easily be in cloudy Weather: How far this is practicable, and with what Charge, they that are skilled in Sea-affairs are best able to judge: In sailing by this Method, whenever they are to pass over very deep Seas, they must sail due East or West, without varying their Latitude; and if their Way over a Sea doth not lie due East, or West they must first sail into the Latitude of the next Place to which they are going beyond it; and then keep due East, or West till they come at that Place:

In any of the Three first Ways, it may be of some Service to find the Longitude within a Degree; and of much more Service to find it within Forty Minutes, or Half a Degree, if it may be; and the Success may deserve Rewards accordingly:

In the Three first ways there must be a Watch regulated by a Spring, and rectified every visible Sun-rise and Sun-set, to tell the Hour of the Day, or Night:

In the Fourth Way, such a Watch is not necessary: In the First way, there must be Two Watches; this, and the other mentioned above:

In the Fourth Way, it is easier to enable Seamen to know their Distance, and Bearing from the Shore, 40, 60, 0r 80, Miles off, than to cross the Seas; and some Part of the Reward may be given when the First is performed on the Coast of Great Britain, for the Safety of Ships coming Home; and the rest, when Seamen shall be enabled to sail to an assigned remote Harbour without losing their Longitude, if it may be.

Dr. Clarke said, That there could be no Discredit arise to the Government, in promising a Reward in general, without respect to any particular Project, to such Person or Persons who should discover the Longitude at Sea.

Mr. Halley said, That Mr. Ditton's Method for finding the Longitude did seem to him to consist of many Particulars, which first ought to be experimented, before he could give his Opinion; and that it would cost a considerable sum to make the Experiments; but what the Expence would amount to, he could not tell.

Mr. Whiston affirmed, That the undoubted Benefit which would arise on the Land, and near the Shore, would vastly surmount the Charges of the Experiments.

Mr Cotes said, That the Project was right in the Theory near the Shore; and the practical Part ought to be experimented

And, upon the whole Matter, the Committee came to these Resolutions; viz.

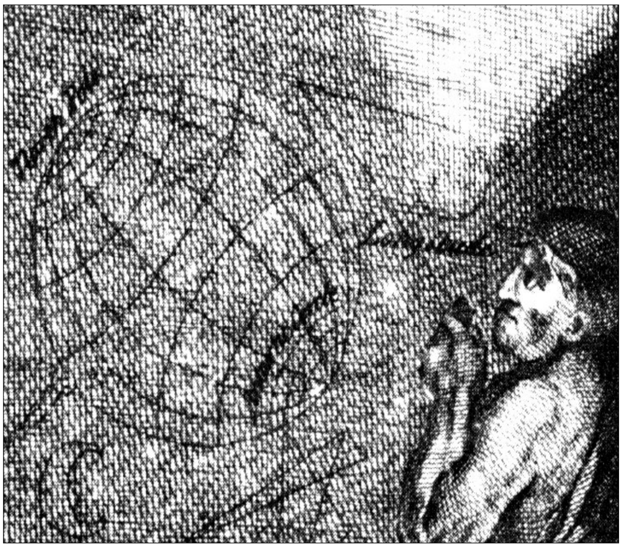
Resolved, That it is the Opinion of this Committee, That a Reward be settled by Parliament upon such Person or Persons as shall discover a more certain and practicable Method of ascertaining the Longitude, than any yet in Practice; and the said Reward be proportioned to the Degree of Exactness to which the said Method shall reach.

Resolved, That it is the Opinion of this Committee, That the House be moved, That Leave be given for a Bill to be brought in accordingly"

Journals of the House of Commons 1714/06/11

From: 'Fourth Parliament of Great Britain First session (3 of 3) - begins 17/4/1714', The History and Proceedings of the House of Commons : volume 5: 1713-1714 (1742), pp. 106-54. URL: http://www.british-history.ac.uk/report.asp?compid=37686

On the 8th July 1714, (just before Queen Anne died) Act 12, Queen Anne, Chapter 15, was passed which offered rewards of up to £20,000 to anyone who could devise a method of calculating longitude at sea. The device must be tested on a voyage to the West Indies and on arrival must give the longitude of the port within a specified degree of accuracy. £10,000 would be paid if the error did not exceed 60 geographical miles, £15,000, 40 miles, £20,000 if the error was within 30 miles. The Act authorised the setting up of a body to administer and evaluate the award, called The Commissioners of the Board of Longitude. It was not a new idea, other countries countries had offered prizes for a satisfactory method for finding longitude.



As well as the serious contenders there were also the nutters. The Board of Longitude had to consider them all at its meetings. Among the inmates of the lunatic asylum in Hogarth's Rake's Progress are those who have gone mad trying to calculate a method of finding longitude.

James Bradley and the Moon

James Bradley was born in 1693 (so he was the same age as John Harrison). His Oxford degree was in theology, but his uncle, James Pound - also a clergyman, who was rector of Wanstead (in East London) was a keen amateur astronomer. Bradley lived with his uncle and aunt and shared with them and visitors like Edmund Halley, their astronomical investigations, such as finding the distance of Mars.

One of Bradley's important discoveries was nutation - the wobble in the precession of the Earth's axis caused by the gravitational effects of the Moon. Other astronomers discovered more about this effect. It was D'Alembert who found this movement of the Earth, which caused the aberration in the positions of the stars was due to the Moon's orbit round the Earth.

The Moon's Orbit and the three body problem

Jean-le-Rond D'Alembert was found in 1717 on the steps of the church of St.Jean-le-Rond in Paris. Amongst his published work were mathematical treatise on the gravitational problems of three bodies or more. For although Newton's laws work well with two bodies, as Newton himself realized, each body in the solar system must be subjected to the gravitational effects of other bodies in the Solar System. The Earth, for instance, is effected both by the Sun and the Moon, and also in a much smaller way by the other larger bodies in the Solar System. Newton had not succeeded in solving this problem mathematically, now others tried to provide a mathematical solution to the three body problem.

Alexis Claude Clairaut, also from Paris, born in 1713, was particularly concerned with gravitational effects of the Earth and Moon and of the planets. He predicted the date of return of Halley's comet, taking into consideration the influences of Jupiter and Saturn. (He was just over a month out).

Leonhard Euler, was born in Basle in 1707. His family was friends with the Bernoulli family of mathematicians. He was employed at the Academy of Sciences St.Petersburg, but from 1741 to 1766 he worked for Frederick the Great in organising the Academy of Sciences in Berlin. In 1735 he lost the sight in one eye, and after returning to Russia, went completely blind. But he continued working as a mathematician.

Euler, Clairaut, and D'Alembert, each found a solution to the three body problem and produced a lunar theory resulting in lunar tables.

The Rival Clockmakers of Paris

By the 18th century the term "chronometer" was beginning to be used for clocks or watches that could be used for navigation at sea. They were still also called "sea-clocks" or in French "horloges-marine" or for the spring-driven watches "montres-marine. The development of a "montre-marine" was to lead to bitter rivalry between two Paris clockmakers.

One of these was Pierre le Roy (1717-1785), the other was Ferdinand Berthoud (1727-1807). Pierre le Roy was born in Paris into a family of established clockmakers. He became *Horologer du Roi* (clockmaker to the King). In the 1750s he started designing and making sea-clocks. His third or fourth design, which was of compact size and spring driven - a "montre-marine", was presented to King Louis XV in August 1766. Trials began on it the following year together with a second "montre-marine" le Roy had made.

Ferdinand Berthoud was born in Switzerland. He worked in Paris, his workshop was down the same street - the rue de Harlay, as le Roy. Berthoud's books on horology made him famous in Britain as well as France and he was made a member of the Royal Society in 1764. Berthoud was also working on the development of a "montre-marine" in the 1750s. His work and reconstruction of him in his workshop can be seen in the Conservatoire National des Arts et Metiers. Berthoud's chronometers were successful in trials. In 1763 and 1766 he was sent by the French Government to London to examine John Harrison's fourth and successful sea-clock. This was seen by Harrison as industrial espionage. Which of course it was.

In 1766 Berthoud received a commission from Louis XV for two "horloge-marine" and in 1770, he was appointed *"Horloger Mechanicien du Roi et de la Marine"*.

Both le Roy's and Berthoud's chronometers were larger than Harrison's fourth machine. They were competing not only with Harrison and other British clockmakers, but each other, leading to bitter rivalry.

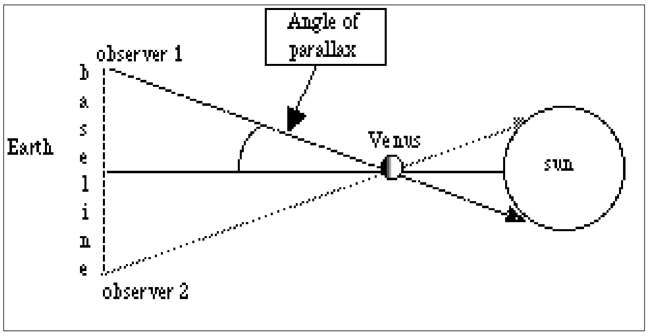
At stake was the chance of lucrative commissions supplying the navy and merchant shipping. Berthoud was to be the winner as his improved chronometers eventually went into production.

More details can be found in the works of Catherine Cardinal on Ferdinand Berthoud.

Transits of Mercury and Venus

The cooperation of British and French scientists, even when their countries were at war, was shown by the great international scientific effort made to record and measure the transits of Venus in the 18th century.

Edmund Halley recognised the importance of observing the transits of Mercury and Venus - the rare occasions when one of these planets gets in line of sight between the Earth and the Sun. It appeared to the observer, using a telescope projecting the image of the sun on white card, *(never look directly at the Sun through a telescope)* as a tiny black dot crossing in a few hours in front of the Sun. See photo below.



By timing the exact moments that the planet entered and left the Sun's disk, by astronomers observing from different places on Earth, it was realised that by using parallax, it was possible to determine the distance of the Earth from the Sun. And then to use that as a baseline, the Astronomical Unit, to find the distance of other objects in the Solar System, and the nearest stars. It would also be possible to determine the longitude of the position of the observer. Observations of the transit of Mercury in 1677, were used to determine the longitude of a number of places including, Port Royal, Jamaica.

Major international preparations were made for astronomers despite political problems and even wars, to travel to remote parts of the world to observe the transits of Venus in 1761 and 1769. They knew a similar opportunity would not reoccur again until 1874 and 1882. The most recent transits were in 2004 and 2012. Picture of the transit of Venus was taken by Heather Hobden from back garden in 2004. The astronomers had some amazing adventures on their travels to their destinations in Canada, Tahiti, South Africa, Central Siberia, India, Mexico, and other far-flung parts of the Earth.

More on this can be found in “The Whisper and the Vision, the Voyagers of the Astronomers,” by Donald Ferner, published in Toronto, 1976.

and Nevil Maskelyne

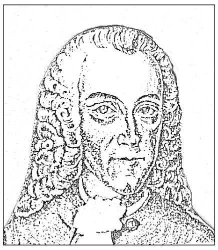
In January 1761, The Rev. Nevil Maskelyne was sent to St.Helena in the Atlantic Ocean. Maskelyne, who was to become Astronomer Royal at the age of 32, had been born in 1732 into a wealthy land owning family. He was sent to Westminster School, then to Trinity College Cambridge where he studied for a degree in divinity. In 1755 he was ordained and given the curacy of Barnet *(in North London)*. He became a close friend of the Astronomer Royal, Bradley.

Maskelyne was to have been accompanied to St. Helena, by Charles Mason, a professional astronomer at the Royal Observatory, Greenwich, but Mason was sent with Jeremiah Dixon to Bencoolen in Sumatra. Mason and Dixon had barely started out when a French frigate in the Channel attacked their ship. They set out again, the Royal Society who sponsored the expedition refused to admit they now had no chance of getting to Sumatra in time. When they reached Cape Town, they heard that Bencoolen had been taken by the French, so they remained in South Africa. It was as well, for no other observations were made in the South Atlantic. The Rev. Nevil Maskelyne, with astronomer Robert Waddington on St.Helena, had a cloudy day. His journey was not wasted, for he had also been told by Bradley to test the new lunar tables by Tobias Mayer for finding longitude by the lunar distance method.

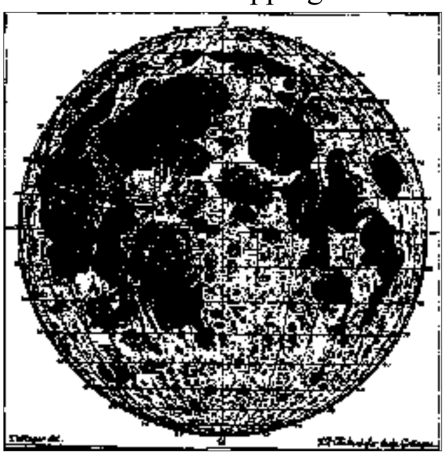
Mason and Dixon's results from South Africa had too many discrepancies in the timing to be of use. All the results were flawed because of the "black drop" effect when Venus began to cross the Sun's disc. (Caused by its atmosphere).

In 1961, the distance of Venus was found by bouncing radar signals off the surface of Venus, using the radio telescope at Jodrell Bank to transmit and then receive the echoes, hydrogen maser clocks, and the cooperation of other observatories in the USSR and the USA. Even then they had to settle on a mean average of the results to get a distance for the astronomical unit (149,6000,000 kilometres).

Tobias Mayer (1723-1762)



Tobias Mayer was an astronomer who worked for the Homann Cartographic Bureau in Nuremberg, and was employed in established accurate coordinates for maps. For this he used the Moon's eclipses and occultations of stars by the Moon. Hence his interest in mapping the Moon and in reliable lunar tables. In this work he was helped by his correspondence with Euler.



In 1751 Mayer was appointed professor of mathematics and political economy at Göttingen University and in 1754 was put in charge of the observatory. By this time his lunar tables were ready and he sent them to England to submit them for the award offered by the Board of Longitude. Mayer could see that these tables would be of use in calculating longitude by the lunar distance method.

Publication of Mayer's Lunar Tables

Mayer died of septicaemia in 1762. His wife brought the latest edition of his lunar tables to the Board of Longitude in London, to be assessed for the award. In 1763, Maskelyne published them in his book" The British Mariner's Guide". Mayer's name as author of the tables does not appear on the title page. Maskelyne gives the impression that it is all his own work.

Later Charles Mason published a Revised Version of Mayer's lunar tables. He did give Mayer full credit as the original author.

Mayer's widow received £3,000 in 1765 from the Board of Longitude who also paid Euler a much smaller sum in recognition of his contribution.

But by this time there was a serious challenge to the lunar distance method of finding longitude, John Harrison's fourth sea-clock.

THE
British MARINER'S GUIDE.
CONTAINING,
Complete and Easy Instructions
FOR THE
Discovery of the LONGITUDE at Sea and Land, within a Degree, by Observations of the Distance of the Moon from the Sun and Stars, taken with HADLEY'S Quadrant.
To which are added,
An APPENDIX, containing a Variety of interesting Rules and Directions, tending to the Improvement of Practical Navigation in general.
And a Sett of correct
ASTRONOMICAL TABLES.

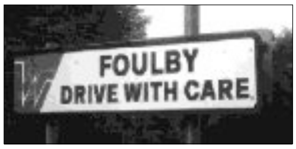
By NEVIL MASKELYNE, A.M.
Fellow of TRINITY COLLEGE, CAMBRIDGE, and of the ROYAL SOCIETY.

LONDON:
PRINTED for the AUTHOR;
And Sold by J. NOURSE, in the Strand; Mess. MOUNT and PAGE, on Tower-Hill; and Mess. HAWES, CLARKE, and COLLINS, in Pater-Noster-Row.
M DCC LXIII.

MAYER'S
LUNAR TABLES,
IMPROVED BY
MR. CHARLES MASON.
PUBLISHED BY ORDER OF THE
COMMISSIONERS OF LONGITUDE.

LONDON:
Printed by WILLIAM RICHARDSON, Strand;
AND
Sold by P. ELMSLY, Bookseller to the said COMMISSIONERS.
M DCC LXXXVII.

John Harrison's Origins



John Harrison was born early in 1693, the first child of Henry and Elizabeth Harrison in Foulby. On the A638 near Wakefield, West Yorkshire, Foulby is (and was then) just a few houses on the estate belonging to Nostell Priory surrounded by farms and coal mines. Subsidence from the mining means that few houses survive that were standing in 1693.

The house in which he was born was a low thatched cottage, with two rooms, one used as a living room, and the other as a sleeping room. and was pulled down in the 19th century –but the strong wooden door was kept for several years.

The mines where many of their neighbours worked, were mostly small bell-mines at this time, each owned and run by a family who all worked down the mine, naked in the dark and dust. The miners dug a shaft into the ground, and then worked out the coal seam until it collapsed. Meanwhile their wives dragged out the spoil in a basket, crawling out of the shaft and heaving it up a long ladder to the surface. Elizabeth's life was hard working – she had a farm as well as her home to run – but she was much better off than a miner's wife.

Her husband, Henry Harrison was employed as joiner and surveyor by the owner of Nostell Priory, Sir Rowland Winn. Winn was particularly interested in wood, and was to employ furniture designer Thomas Chippendale. Winn was growing the trees to be transformed into this new stylish furniture, and one of Henry Harrison's responsibilities was maintenance of the woodlands. Winn's main estates were on South Humberside and Henry Harrison was responsible for the timber there as well. This may be how he noticed that Barrow-on-Humber would be a good place for establishing his own joinery business, since there was, and still is, a wharf where ships bring timber from Baltic countries.

The Harrisons moved to Barrow-on-Humber when John was about three. His sister Mary was two years younger. They lived in a house in the centre, facing the green and the stocks. Elizabeth had more children. Henry, born 1702, James born in 1704 and Elizabeth who died in infancy.

In setting up on his own, Henry Harrison was following a trend. More and more small workshops (many becoming huge factories) were being set up by entrepreneurs and craftsmen over the Midlands and other parts of England, each producing manufactured goods and networked to each other to combine and make individual parts of complete items. This networking was helped by the establishment of an increasing number of local societies (like the Spalding Society – Newton was a member) following the pattern of the Royal Society – but far more open to assorted members –giving them lecture meetings, access to a library and to published journals of correspondence and letters and articles and news. The Lunar Society of Birmingham is the most famous of these.

The Harrison's were far from isolated in Barrow – just across the river and easily accessible by the twice daily ferry or a small boat, was Hull, the third largest and most important (after London and Bristol) international port in England.

Henry Harrison's workshop not only made coffins and cupboards, 18th century carpenters and joiners were also engineers. Since metal was still so expensive before mass production became possible, much of the machinery used in mills etc. was also made of wood.

Henry Harrison's house was detached, with two dormer windows in the roof, and a cellar beneath. There was a well for water at the back of the house, and substantial outbuildings around a yard, for storage and for their animals – a cow for milk and butter with her new calf, a horse for the cart, some sheep for wool which was also sold in their shop. Like most of the middle-classes at this time, they were also farmers, with an acre or two of wheat, beans, barley, peas, etc. to provide for themselves each year.

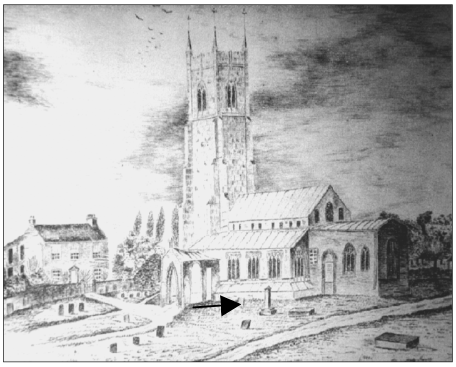
There is a story that John was given a watch to play with when he was ill with small pox at age six. And that this fascinated him so much that he was always to be seen playing with clock parts and putting them together. This indicates that the Harrisons were fairly well off. Only the wealthy could afford watches – and certainly they had to be to allow a child to play with one. Clocks were expensive items. Most people at that time had to rely on public clocks. A clock in your living room was a status symbol.

Barrow, at the end of the 17th century was a fairly prosperous small town still run on the mediaeval open field system. This meant that the town was run cooperatively. The fields were sown in a four yearly rotation of crops, and regulations laid down for pasturing livestock, which was cared for collectively.

The responsibility for the upkeep of the banks of the Humber was shared, with each household being responsible for a section. This was very important as there had been devastating floods. The fields near the Humber were salt marsh and not suitable as arable land.

Henry Harrison had responsibility for the maintenance of part of the river bank and he also had an acre of one crop such as wheat and an acre of another crop such as barley and of another such as beans. The crops were owned, the amount of land in the fields, they grew in was rented each year. His cow, horse and sheep grazed on the meadows.

Henry Harrison also played an important part in civil life. In addition to the responsibilities that fell to him as a property owner, he was a churchwarden and the parish clerk. As parish clerk he was responsible for the maintenance of the church and for taking care of the church bells. He also had to ring a bell four times a day to help people keep time, and also on festive occasions, special occasions and funerals. Everyone in the parish had to contribute to the fees for his work at the church.



Barrow church, shortly after 1731 – the sundial made by James Harrison from the remains of an ancient stone cross, as a memorial to his parents in 1731 can be seen.

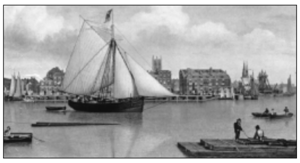
The church was central to the community at that time, for everyone was forced to attend all the services by Act of Parliament. And when you were inside the church, you could not escape by dozing off as it was one of the responsibilities of the sexton to prod sleepers awake.

There was a school run by the incumbent, who at around this time was also headmaster of the grammar school in Brigg, and there were also one or two other small privately run schools in Barrow. The church at Barrow-on-Humber, benefited from a recent bequest which provided for an additional sermon or lecture on Sunday afternoons. The minister could give this, but very often he arranged a visiting lecturer. The lectures were not confined to religious topics but could be on anything suitably educational. The Harrisons were able to meet and entertain in their home some interesting people from academic life. One of them gave Harrison a book of lecture notes from lectures given by Nicholas Sanderson, Newton's successor as Lucasian Professor of Mathematics at Cambridge.

As a boy, John Harrison was trained in his father's workshop as a joiner. A journal kept by one of Harrison's neighbours mentions paying Henry Harrison 9 shillings for his mother's coffin and other things for her funeral in 1721. (Joiners also acted as undertakers). As well as prepared timber, amongst the things they had in their shop were: guns, gunpowder and shot, files, chisels, "bodies" and "stomachers" (*stiffened with wood for the fashionable flat front, pushed up cleavage)*, buckles and spurs, linen, cotton, flannel, buttons and thread, and unprepared wool, carders, dishes, ladles, tubs, ropes, tar, soap, and many dried goods, like sugar, rice, raisins, starch and blue *(made whites whiter)* as well as ironmongery.

John also helped his father with the maintenance and tuning of the church bells, sang in the church choir and later became choirmaster. This was to be very influential in the development of his scientific ideas, which were very much tied in with his interest in music. Harrison spent much of his life in working out a new scale of music wanting to improve the sound of amateur choirs singing psalms in churches. He sets out his ideas in his final work "Concerning Such Mechanism...". He thought the singers and musicians should be paid for their performance in churches.

Barrow is on the opposite bank of the Humber to Kingston-upon-Hull. A ferry operated daily from Barrow Haven, where the post road terminated at a large inn provided for passengers waiting for the ferry across to Hull. Locals also rowed or sailed across to Hull in their own boats. The Harrisons used and may have owned at least one boat of their own. Many of their neighbours kept a riverboat and a small skiff. They used and may have owned a building (recently demolished) down by the wharf at Barrow Haven.



During the 18th century, Humberside became heavily industrialized and Hull a major international port comparable with London. Ships came up the Humber with cargoes from all over the world. From the Humber estuary, freight could be carried by water, not only overseas, and along the coast, but inland up waterways like the Trent, which led into the heart of the Midlands. The Humber was described as a forest of masts and red and white sails. Red for inland shipping and white for the ocean going ships. Rafts of logs and little skiffs.

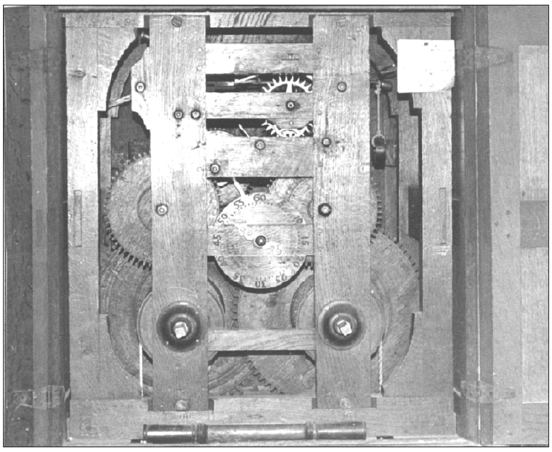
The main import, timber from the Baltic, was also unloaded at the wharf at Barrow Haven. When the tide came in, the timber was floated up the creek past the inn, the windmill, under the post road, past the watermill, round the ancient ruined fortress (originally iron age, then mediaeval) through the fields, and into the centre of Barrow behind Henry Harrison's workshop.

The presence of archaeological remains did not stop the field (called The Castles) being ploughed in its turn, despite the interest shown by famous Lincolnshire pre-archaeologist, the Rev. William Stukeley. He visited Barrow at the time Harrison lived there and thought the castle to have been built originally by Druids. Barrow also has the ruins of Thornton Abbey, greatly refurbished for the visit of Henry VIII who then closed it down.

John started making clocks as a teenager, and since he was trained as a joiner, his first clocks were nearly all of wood. In the early 18th century, this was not so strange as it seems now. Before mass production was developed, iron, steel, brass, and other metals were very expensive, and the quality inconsistent and unreliable. Most industrial machinery in the mills was of wood, and wooden mechanisms, including wooden clocks were usual. Making and repairing machinery in mills and other engineering projects were to provide much of the employment of the Harrison workshop. His brother James was to concentrate his work on industrial machinery, clocks and bellfounding. It was not remarkable for a joiner to be involved in making clocks.

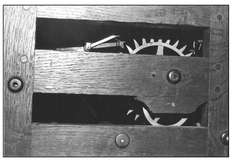
Harrison's early clocks are noted for two innovations. One was the "grid-iron" pendulum. Metal expands when warm and contracts when cold, each different metal at a different rate. So the metal pendulum rod of a clock is longer in hot temperatures than in cold and this affects the going rate of the clock. Making the rod of the pendulum as a number of linked rods of different metals helped keep the pendulum rod at a constant length at different temperatures. Many years later, Harrison incorporated this idea into his watches as a bimetallic strip. This has been used in thermostats up to the present time. The other innovation was the grasshopper escapement, which can be seen in the Brocklesby Park clock.

The turret clock, signed "Harrison" "Barrow" can still be seen in the place for which it was made, the stables at Brocklesby Park, which is now owned by Charles Pelham, Earl of Yarborough.

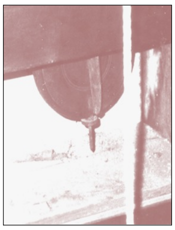


The Brocklesby Park clock is one of the few survivors of John Harrison's work at Barrow-on Humber, where he spent the best part of his life. It is important as showing part of the process of the development of John Harrison's scientific ideas.

The clock originally had a form of equal impulse escapement using frictional pallets mounted in frames.



John and his brother James fitted an early form of pusher type grasshopper escapement, probably in an attempt to overcome the stopping of the clock when the oil dried on the pallet faces. Without the frictional losses of the original pallets, the amplitude must have increased alarmingly.



To try and reduce the arc of swing, air-damping vanes were fitted to the pendulum bob. This reduced the arc of swing but introduced instability into the motion of the pendulum that can still be observed today. The arc of swing increases to a point where the pressure of the increased air resistance causes a tilting of the pendulum around the suspension point close to the bottom of the long suspension spring. The escapement impulse increases the amount of tilt, greatly reducing the force applied to the whole pendulum. Both the arc and the rate of the clock change rapidly, the tilting effect is reduced and the cycle repeats in an irregular fashion.

John Harrison made careful studies of the environmental behaviour and characteristics of different materials - part of his training as a joiner. He had access to offcuts of new materials that ships brought down the Humber from exotic parts of the world, which he used experimentally in his clocks.

By 1726, the Harrisons, John and his brother James, were building longcase clocks that could keep time to 1 second a month.

With the improved grasshopper escapement, roller pinions of lignum vitae, the gridiron pendulum and circular arc cheeks they had a clock that would run without oil.

Their success with these clocks led them to consider the possibility of building a longitude timekeeper using the same technical means.

The close proximity of Hull, the third major port in Great Britain, meant that the nature of the problem and of the huge prize on offer was well known to them.

About the same time, John's life changed. John had been married on the 30 August 1718, at age 21, to Elizabeth Barrel. They had a son, John, less than a year later. John's sister had already married at age sixteen to William Jackson, and had a daughter Mary soon after. So Henry and Elizabeth Harrison were grandparents, and it seems that John was running the business with his brothers.

On the 18th May 1726, John's wife Elizabeth died. Later that same year on the ninth of November, John's brother Henry married Grace Marris. They had a daughter Mary the following spring.

John was soon to follow his brother up the aisle later the same month on the 23rd November 1726. He had not remained a single parent for long. He married Elizabeth Scott, ten years younger than himself.

They bought their own house on the Barton Road, which was just round the corner from Harrison's parents. The house was demolished in the 1960s, soon after this photo was taken. Now this area is covered with modern housing.

Elizabeth had two children, William born in May 1728, and Elizabeth, born in 1732.

A great advantage of John’s home was that it faced south. From his bedroom window, he was able to line up sights with a neighbour's chimney across the road, so that when a star emerged from behind the chimney, it crossed the north-south meridian, and this enabled him to calculate the precise sidereal time.

Henry Harrison, his father, in his will made on 20th November 1726 – that is after his son Henry's wedding and three days before John's second marriage, had stipulated that the house and everything should be passed on after the death of his wife to his second son Henry. Elizabeth his wife appears to have died soon after her husband. So their son Henry inherited the business. But Henry, died on the 23rd May 1729, aged only 27, leaving his wife Grace and two-year old daughter Mary to inherit the shop.

His surviving brothers with the help of two neighbours made an inventory, which tells us what was in the home and shop. The estimated value of all the contents of the home and shop came to £151. 15s. 5d. (*This gives some idea of the value of the awards paid by the Board of Longitude and the costs of Harrison's clocks and watches.)*

In 1731 James constructed a sundial from the remains of an old cross in the churchyard, as a memorial to his parents. John was now running his own workshop in Barrow with his brother James working for him.

The First Sea-Clock

Soon after his second marriage, John Harrison took his designs and specifications for a "sea-clock" down to London and obtained an interview with the Astronomer Royal, Edmund Halley, at the Royal Greenwich Observatory.

Halley was very encouraging and recommended John to visit George Graham.

Graham was one of London's top clockmakers, but not a pleasant man even rejecting his own two children. John Harrison was warned by Halley "not to mind something repulsive in his first reception".

Harrison arrived at George Graham's place at ten in the morning, And "after they got the ice broke" – according to Harrison, he was invited to dinner and did not leave until after eight at night.

Graham arranged for sponsors to contribute money to fund further development. He informed the Board of Longitude that *(according to the book by Harrison's grandson-see page 31)*: "Mr. Harrison hath been ten years from first to last employed on the said machine, and been at very great expense in employing several persons to assist him in making the same, and that, in his opinion, it may in all probability effect when completed, the finding of the longitude at sea".

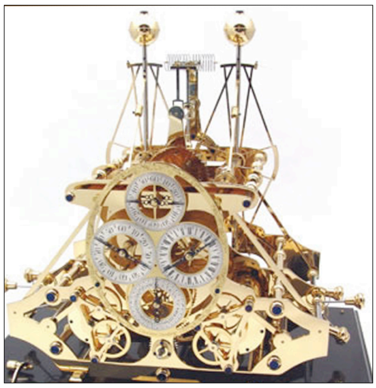
Graham questioned Harrison very closely on his fundamental ideas, he possessed an excellent library and would have shown Harrison the current theoretical thinking as exemplified by Newton's 'Principia'.

Harrison's insistence that a large arc of swing and great vis viva or energy of motion ran contrary to the received wisdom of the time. This continental hypothesis originated with Huygens and was the basis for Robert Hooke's ideas.

However, it is inherent in the phase plane analysis used by Newton in the 'Principia'and formed the basis of his analysis of errors in pendula motion. Harrison's approach was definitely based on phase plane arguments.

John Harrison returned to Barrow with a loan from George Graham, believed to be of £250. This was an astonishing act of generosity on Graham's part and was crucial to the Harrison's ability to proceed with building a practical machine.

At this date, the Board of Longitude had never met to consider a practical solution in the form of a timekeeper. Graham obviously considered that working hardware would do much to sway the Board in favor of timekeepers as an alternative to the lunar distance method. At this time, no practical mathematical solution existed for the theory of the moon's motion that would allow useful tables to be constructed.

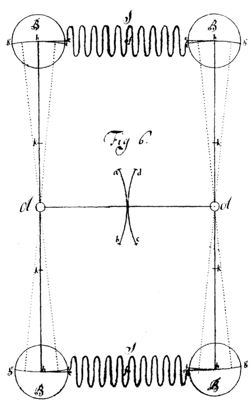


Harrison was awarded a grant of £500 as an official candidate for the longitude prize.

This machine incorporates much of the technology developed for the precision regulator clocks, lignum vitae roller pinions, anti-friction rollers to support the balance arbors and the grasshopper escapement. Like the precision regulators, it needed no oil. Contra-rotating bar balances with the balance springs at their extremities were linked using thin steel strips. These strips ran on the surface of circular arcs, concentric with each balance arbor, with the strips pinned at each end. The balances were to beat seconds - this was to prove to be a mistake as this is far too close to the periodicity of motion of the small sailing ships of this period. Picture shows a replica based on H.1 by the firm of Sinclair Harding.

Development Problems:

John Harrison originally planned the temperature compensation to use movable weights, moved directly by gridirons mounted on each balance. George Graham correctly predicted that this would not work - the whole mass of the balance at the radius of gyration would have to be moved in order to compensate for the loss of elasticity of the steel spring. Harrison however, tried this approach only to discover that George Graham was right - a steel and brass linear gridiron can never provide sufficient compensation. He was therefore forced to apply temperature compensation to the spring itself, by using doubled gridirons and multiplying levers to alter the effective working length.



This was the first ever balance controlled timekeeper with correctly working temperature compensation. The contra-rotating balances would compensate for simple rolling, but not for more complex motions involving yaw and pitch. Robert Hooke had proposed a much more complex arrangement involving orthogonal balances interconnected so as to compensate for all possible motions -not a practical solution. Picture shows copy of drawing in Harrison's proposal.

The machine's large size was the main problem - however, it was a prototype, the first stage of a development process.

John and James tested their "sea-clock" aboard a Humber keel they kept moored in the estuary off Barrow Haven. They used lamps to signal between the boat and a building on the wharf at Barrow Haven. This building was demolished in the 1980s.

The results were very encouraging and Harrison took the machine to London

The First Machine Under Trial

With Graham's and Halley's support, Harrison obtained a certificate signed by five members of the Royal Society. This was presented to the Admiralty, together with a petition requesting a sea trial.

Lisbon was chosen as its longitude was known, established by James Bradley using observations of Jupiter's satellites. They would therefore be able to check how closely H1 kept time to a known meridian.

In 1736, the sea-clock was ready for its official trial. John accompanied the clock on a navy ship, HMS Centurion, to Lisbon. On the return voyage on HMS Orford, he was able to correct the captain's estimate of the ship's position by 58 nautical miles.

The outward voyage in the 'Centurion' and the return in the 'Orford' showed that the Harrisons were working on correct lines.

Harrison was able to correct the ship's position as it entered the English Channel, calculated from 'dead reckoning', by some 90 miles. This shows how hazardous navigation was in the 18th century, with no accurate method to correct dead reckoning estimates.

The master of the 'Orford' gave Harrison a certificate to the effect that he had corrected the ship's position; 'his observation showed the ship to be more west than my reckoning, above one degree and twenty-six miles.' The results and reports from both ships' captains were good enough to be worth further funding.

The Second Sea-Clock

The first sea trial had revealed that their sea-clock had a number of deficiencies.

Firstly, when mounted in its case on gimbals it was far too large - about 4ft square. (It was suggested that if the ship were attacked the assailing ship could be sunk by throwing the chronometer at it!)

Secondly, the drive from the train was not sufficiently stable - particularly in recoil and prone to disturbance from ‘stick slip’by the uncoiling mainspring.

Thirdly, the temperature compensation suffered from lag in operation -due to the small area of the reversed grid-irons and the complexity of the multiplying levers.

John and his brother James set out to make a new machine to remedy both these deficiencies. A new form of temperature compensation was devised, using longer rods and a much-improved linkage to act on the balance spring. Secondly, an auxiliary spring was used, rewound every 30 seconds to drive the escapement. This device, a train remontoire, was to become a standard feature of all the future Harrison designs. The second machine also required access to the greater resources of mechanical production technology in London.

Moving to London

From Barrow there were two direct methods of getting to London, by road or by sea. Both ways of travel took a few days so to the expensive fares had to be added meals and accommodation costs. Barrow was on a direct post-route. But the roads were poorly maintained, and the coaches frequently broke down making them sitting ducks for the highwaymen. At this time the famous highwayman, Dick Turpin was working that very route south through Lincolnshire to London. Harrison probably found it more convenient to travel to London by boat. There were many ships making frequent regular trips from Hull and even Barrow Haven. They were however, likely to be attacked by pirates, or flounder in bad weather.

It may have seemed a good idea to move to London, since travelling back and forth between London and Barrow took up so much time and was so expensive. But when they arrived, it must have been very difficult, especially for Elizabeth.

Their first home was in Leather Lane, Clerkenwell, which is not far from Hatton Garden off the lower end of Holborn. The buildings were old – this area escaped the fire, which had destroyed the city 75 years earlier. There were industrial workshops, and a market down the street, so it was noisy, dirty and crowded.

This was the London in Henry Fielding's novel "Tom Jones". John's eldest son, like the hero of Fielding's novel was new to London and all it had to offer a young man of eighteen. But by the 16th May 1738, he was dead.

Meanwhile John and his brother had been completing their second sea-clock. The engraved inscription on the clock (now called H.2) reads "John Harrison fecit. Made for His Majesty George the IIrd, by order of a Committee held the 30th of June, 1737". His brother's name does not appear on the clock, although apparently he also worked on it.

The second machine was of more robust construction. (Picture shows replica by Malcolm Leach). The temperature compensation had been much simplified, with two thick steel rods running nearly the full height of the back plate. Four thin brass rods, two either side of each steel rod are connected via a much simpler lever system to the movable arms which control the tension in the balance springs.

The grasshopper escapement is driven via a constant force remontoire, rewound every 3.75 minutes. This isolates the escapement from variations in force from the train and mainspring and provides a constant force in recoil -very important to the proper operation of the grasshopper.

The second machine incorporated the lessons learnt from the first (H.1). It is smaller, but heavier (86lb.). There are no longer wooden wheels in its construction, although the use of lignum vitae is maintained for the roller pinions and the grasshopper pallets. It is the first machine to use a train remontoire.

This was probably, apart from the use of bar balances, the best and most stable of the large machines.

During the testing, a flaw was revealed. The contra-rotating balances, originally thought sufficient to compensate for the rolling of the ship were found not exactly to do so. Worse, they were greatly affected by the yawing motion, as the ship rotated in the plane of the sea surface, the prow moving backwards and forwards along the line of the horizon. While rolling is a cyclical motion whose overall effect leaves a small residual error, this was not true for yaw. Yaw produced a strong force at the balance pivots, at right angles to the plane of motion. Dependent on the seaway, this error was cumulative and could produce a large, accumulated error. It was never tried at sea and remained in Harrison's hands until it was removed by Nevil Maskylyne in May, 1766.

John had decided to abandon this machine and start again.

The Third Machine

The Committee of the Board of Longitude on June 30th 1737, who had approved his second machine for keeping the time at sea, had noted in their minutes of that meeting that Harrison "proposes to make another machine of smaller dimensions within the space of two years, whereby he will endeavour to correct some defects which he hath found in that already prepared…".

In 1739, James moved back to Barrow. John was left to continue research and development of a third "sea-clock" on his own. The full story is not known. At least partly it may have been that James could see that they had no chance of completing a third machine satisfactorily within the agreed time limit of two years and had abandoned his part in it. The family rift was not total, as John Harrison and his family still visited Barrow and regarded it as home.

James moved into his brother's house on the Barton Road. His business prospered and he acquired extensive property including a bell-foundry, a mill, and houses at Middle Rasen where he eventually made his home. He was to die in Middle Rasen in 1766, but was buried in Barrow. James and his wife Thomasin had ten children, founding a dynasty in engineering, including clocks, machinery for mills, and bell founding, in North Lincolnshire and Hull.

In 1739, John and Elizabeth, with their remaining two children, also made a fresh start. They moved to a much better area and a new house. This was in the new development of terraced town houses around Red Lion Square, just off High Holborn. The area was then a middle-class suburb of London. Lawyers traditionally lived here at the Inns of Court and other trades and professions. Nearly all London's clockmakers and instrument makers had their workshops in the Holborn and Clerkenwell area so they were all within easy walking or sedan chair distance of the Harrison's new home.

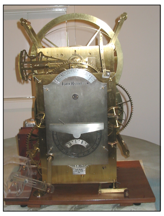
The Board of Longitude had some confidence that Harrison could meet the specifications and produce the clock they required. His early clocks were greatly admired. They were visited by the important and famous. The Lincolnshire historian William Stukeley went to see Harrison's clock (possibly H.1.) which was with George Graham, in 1739, and was impressed enough to describe it in his journal: "*...the sweetness of its motion, the contrivances to take off friction, to defeat the lengthening and shortening of the pendulum thro' heat and cold, to prevent the disturbance of motion by that of a ship cannot be sufficiently admired."*

In January 1741, Harrison wrote to the Board of Longitude about his work on the new, third machine, and received from them £500, to finish its construction. He had a testimonial signed by twelve prominent members of the Royal Society recommending him "as a Person highly deserving of such further encouragement and assistance as they will judge proper and sufficient to finish his third Machine."

After that, progress was slow. During this time, Harrison did continue with his scientific work, not only on clocks and timekeeping, but with his interest in music. He had a respected position amongst the other clock and instrument makers who in 18th century England represented the cutting edge of science and technology.

This machine dominated Harrison’s efforts for the next 17 years. Harrison had miscalculated the size of the circular balances required to beat 1 second with an acceptable value of spring constant k. As a result of this and the use of a spiral spring on the top balance arbor, where the angular displacement is much smaller than was the case with the balance springs on H.1. and H.2., the resultant spring is very short and stiff, 1 7/8 turns.

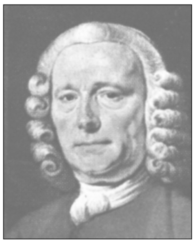
This introduced problems that led to a massive improvement in Harrison's understanding of how balance and spring timekeepers worked. By 1746, Harrison had run out of funds and had to apply to the Board of Longitude for another grant. He included his testimonial from the Royal Society. At the meeting of 4th June 1746, the Board awarded Harrison another £500.



Harrison's third machine (picture shows the replica made by Don Unwin) introduced three innovations; the use of circular balances, a short spiral balance spring on the top balance arbor, and the bimetallic strip or 'thermometer curb' to provide temperature comensation. It is a golden rule of the development process that you do not introduce too many untried ideas at once. Harrison was in trouble with this machine and spent nearly 17 years trying to overcome its strange behaviour.

The bimetallic strip, composed of brass and steel riveted together, was a primary invention that would be used in one form or other on all the timekeepers that followed. It is mounted on the 'fiddle frame' adjacent to the top arbor. This picture shows the fiddle frame carrying the bimetallic compensation curb. The frame is mounted so as to allow the position of the curb pins to be adjusted with respect to the balance spring. The operational length of the curb may also be adjusted, by means of the slider mounted in the centre of the frame.

In 1749, one of Harrison's friends and supporters, Martin Folkes, had become President of the Royal Society. Harrison was awarded the Copley Gold Medal, which was given for: "the most important scientific discovery or contribution to science by experiment or otherwise".



From photo by Mike Lincoln of original mezzotint in the collection of the late Gerald Penn.

In 1752 the Harrisons moved to a corner house with an entrance on Red Lion Square. Corner houses were in a coveted position, having larger plots and better access.

In 1753 John Harrison was 60, and it is shortly after this that he had his portrait painted. It cannot be much earlier for he is holding the new deck watch he designed. It could not be after 1759, for in this portrait he is sitting surrounded by his life's greatest achievements. Behind him is his third sea-clock (H.3.) in its case and the long-case regulator, which he used in his workshop. This latter has its door open to reveal the innovative grid-iron pendulum. His hand holding the watch is resting on a table covered with one of his drawings.

At the time it was painted, his portrait could be viewed as showing the main achievements of a successful working life near completion. The artist, and even Harrison himself, could not have known when it was painted, that his greatest achievement and the work for which he is still famous was yet to come. The portrait shows a small man with brown eyes and time ravaged complexion with marked lesions. He is seated on a fashionable carved chair, wearing full wig (also fashionable and expensive), a brown suit and a plain shirt. (His grandson was later to write that he refused to wear the lace-edged shirts then in fashion for men even when he had an audience with the King). A later copy of this portrait is more conventionally flattering and has the watch on the table instead of in his hand.

Although Harrison's portrait may originally have been commissioned to go on a 'wall of fame' at the new Society of Arts, it is strange that no family portrait is known to have existed. Both John Harrison's surviving children helped him in his workshop as they grew up. Elizabeth married John Barton and had a son John, who was to inherit the house and workshop in Red Lion Square. William married a Yorkshire girl, Elizabeth Atkinson, ten years younger than himself.

The Winning Watch

Harrison's first three sea-clocks were all very large heavy machines which were intended to be kept in a wooden case in the captain's cabin when on board the ship. Obviously a large clock in the captain's cabin, however accurate, was no use for making observations on deck. Since the 16th century, ship's officers had used a watch to assist their observations from the ship's deck.

Harrison had also been working on designing the very accurate and easily portable watch they needed. He designed a pocket watch using a bimetal compensation curb on a short spiral spring. The escapement is an adaptation of the principles proved with the ‘grasshopper’ - but using a vertical or ‘verge’ escapement and shaped diamond pallets. As the escapement has recoil he introduced an internally toothed third wheel to reduce engaging friction.

In 1753, Harrison employed another clockmaker to make this watch. This was John Jeffreys, who he described as "a Man of good Character and Industry." This is the watch in Harrison's portrait, he used it as his pocket watch for the rest of his life – except when he loaned it to Admiral Duncan, to use for finding longitude.

In the cramped conditions of the 18th century sailing vessel, the more compact the ship's clock, the better. During the 1760s, British and French clockmakers working on designs for a "sea-clock" or "montre-marine", were monitoring each others designs, racing to produce the definitive ship's clock and thus win the orders from the world's shipping. Harrison's H.3. although beautiful and precise, was now looking large and dated. The Board of Longitude was now thinking that the lunar distance method of finding longitude would win the prize.

Harrison realised that the principles employed in the design of the deck watch, could be used in a larger watch, with the improvements, such as a train remontoire, which he had pioneered on the larger machines. He therefore started work on a larger watch to supplement the large machine on board the ship. It was completed just in time for the trials planned for 1761.

It was nothing like the large machines on which he had laboured so many years, it was based on the Jeffreys watch. This was the first watch to contain temperature compensation acting on the balance spring. (See Appendix). Like the Jeffreys watch, H.4. had a bimetallic compensation curb in the balance spring and a similar form of diamond pallets. However, Harrison added a train remontoire rewound every 7 ½ seconds. The balance was 2 1/8" in diameter and the original balance spring was 3 turns, pinned up as on the Jeffrey’s watch of 1753. The vertical escapement ran at a maximum arc of 248. This meant that the spring constant k, had to be large, in order to provide 5 beats to the second with the large balance.

H.4. completed in 1759, is larger than the Jeffreys deck-watch, being approximately five and a half inches across. It is a beautiful object, very decoratively finished, and Harrison was very proud of it. He thought it ought to be on show at the British Museum, which had just been built near to where he lived. It actually ended up on display at the Maritime Museum with his three earlier machines.

The Trial of 1761

Harrison had finally discovered the source of his problems with the third machine (see appendix). He therefore hastily modified the balance spring assembly on the deck watch and to his delight, its performance greatly exceeded that of the third machine. He therefore wanted to test his new watch in place of the planned trial of his third clock. John Harrison felt too old to endure an arduous long sea voyage for the official trials. His son William was to go instead.

In March 1761, the Board of Longitude told William Harrison to take the third timekeeper by sea to Portsmouth, while his father travelled with the fourth timekeeper, the watch, overland. From Portsmouth William Harrison was to take a ship to Jamaica for the trial of the clocks, and was to return on the first available ship home.

The orders came at the wrong time for William, whose wife, Elizabeth, was pregnant. While William waited for the arrangements for his voyage he stayed with John Howard in his recently purchased house and estate, of Watcombe, near Brockenhurst. Advised by his in-laws in Yorkshire, the Atkinsons, William kept a journal of which a number of copies were to be made. His wife wrote to him. She was having a difficult time after the birth, she had a breast abcess and became very ill. After five months of waiting, William's patience ran out, and he returned to London and his family. (His wife died soon after aged only 26).

In October, the Board arranged that the watch (H.4.), should be taken in HMS Deptford, by William Harrison and an astronomer, John Robison, who was to make the observations to fix time and longitude in Jamaica. By this time it would not have been possible to fix the longitudes using Jupiter's satellites, the method originally intended to be used at Portsmouth and Port Royal, Jamaica. Jupiter was no longer visible. Observations of equal altitudes were taken instead.

It is likely that the Board of Longitude and the Royal Society who had sponsored the expeditions to observe the transit of Venus on June 6th 1761, were waiting for the astronomers to return with the results, before committing themselves to expense of the trial of Harrison's sea-clock (or chronometer, as these timepieces were to be called). Especially as Maskelyne was testing the usefulness of the lunar tables by Tobias Mayer, on the lunar distance method of finding longitude.

Harrison's large chronometer was not very practical even if accurate enough because it could not be used when making the observations on deck. So if the new lunar tables proved accurate enough they could qualify for the prize from the Board of Longitude. But the Harrisons were now insisting that the trials be made on their new watch, which was portable and convenient. (It was also extremely expensive, but the Board of Longitude did not know this yet.) If it worked it would provide a far better and quicker method of finding longitude, than by using astronomical methods alone.

William Harrison's suspicions that Bradley was hoping for a prize by using Mayer's new lunar tables with the lunar distance method, were confirmed after the meeting where the final arrangements for his expedition were made. With his father he visited John Bird, the scientific instrument maker and designer who was working on the instruments he would need. Here the Harrisons saw the Astronomer Royal, James Bradley, who had also been at the meeting of the Board of Longitude as he was one of the Commissioners.

William Harrison noted in his journal:

The doctor seemed very much out of temper and in the greatest passion told Mr. Harrison that if it had not been for him and his plaguey Watch Mr. Mayer and he should have shared Ten Thousand Pounds, before now. This gave Mr. Harrison an opportunity of seeing what sort of a Friend Dr. Bradley had been at the Board, who formerly had been one of the best friends Mr. Harrison had, but now Self Interest seemed to be the Principle.

It was November 1761, when William Harrison departed on HMS Deptford for Jamaica, with the watch H.4. The route lay south first then they would catch a prevailing wind which would carry them west across the Atlantic to the West Indies.

After they had been at sea a few weeks, all the cheese, much of the other food, and all the remaining beer was found to be unfit for consumption and had to be thrown overboard.

On December 9th, the Master's journal bore the alarming entry:

"This day the Ship's Beer is all expended, the People obliged to drink water."

William Harrison described in his journal how his watch saved the situation:

On the 8th by Observation, the Deptford was in Latitude 37^{o}-$17^{'}$ by the Watch 15^{o}-$17^{'}$ West from Portsmouth, but by the Ships Reckoning, was not so much West by a degree and a Half; and most of the Ships Company were so confident of their Reckonings, that they wanted to Steer more to the West, being in want of Beer, and afraid of losing Time. But the Captain would not alter his Course, though at the same time, would have laid five to one, that he was three days run too much to the East; but he said, he would stand on, until the next Morning, since Mr Harrison did affirm, that if the Island of Porto Santo was laid down right, they must see it the next Morning.

And accordingly, at Seven o'clock in the Morning it was seen; on which the Captain, as well as the Ships Crew, were very thankful to Mr Harrison, for keeping the Reckoning by the Watch; without which they would have Steer'd in the West of Madeira, at the same time they thought themselves to the East, and so not have seen the Island at all; the Consequence of which, would have been Inconvenient, as they were in want of Beer."

They were able to stock up the ship with several barrels of Madeira wine and continue to Jamaica where they arrived on the 19th January 1762, after 81 days at sea, for the official tests of the clock. Robison set up his instruments and established the local time. When compared with Harrison's watch the difference was only 5.1 seconds in 81 days. Ships that arrived after the Deptford were as much as 20 minutes out in their calculations, which would put them nearly 350 miles from their correct position.

William Harrison departed for England on January 26th 1762, on the Merlin. The weather was bad, the Atlantic rough. William was forced to keep the water out of H.4. by wrapping it in a blanket. As the blankets became damp, he dried them by sleeping in them. In consequence he became very ill. He arrived back home on 26th March 1762.

The expedition should have been worthwhile. The watch performed successfully. The terms of the award were that the chronometer should be accurate to within two minutes. The Harrison watch, after the round voyage of 147 days had a total error of 1 minute, 54½ seconds. But the Board of Longitude did not accept the results of the trial.

A possible reason for this is that they had also been supporting Maskelyne's trials of Mayer's lunar distance tables. They knew this method of finding longitude was much more time-consuming and complex. It took Maskelyne, expert in this method, three to four hours to make each observation and reduce the result by calculation. In the books on navigation, the method using a chronometer takes up about one paragraph, the lunar distance method takes several pages to describe. Compiling the astronomical tables also required the employment of a great number of men and women called "computers" who were sent their allocation of calculations, which then had to be collected and checked.

Maskelyne, although still only thirty, had acquired a great deal of influence. With Mayer dead, and Bradley dead also, Maskelyne hoped for the prize. Nathaniel Bliss succeeded Bradley as Astronomer Royal, but he was seriously ill and had not long to live. Maskelyne was to become Astronomer Royal in two years time. Not just the Harrisons, but other clockmakers making chronometers were to discover, that Maskelyne, even if he could not claim the award from the Board of Longitude himself, put every obstacle in the way of a 'mechanic' winning the prize with a chronometer.

Dispute With The Board Of Longitude

At the meetings of the Board of Longitude which followed the trial of Harrison's time-keeper, the committee insisted that William Harrison had not taken sufficient care in ascertaining the local time in Jamaica by the method of equal altitudes of the sun. William had moved the instruments between the morning observation, and the afternoon observation, and that, the Board said, would introduce an error.

William insisted that the 49 sets of observations taken by himself and Robison, showed a deviation of less than two seconds, and great care had been taken with the levelling of the instruments. The Board passed the observations to computers for checking. When William Harrison was summoned to the following meeting of the Board of Longitude on the 17th August 1762, he asked to see the results of the calculations and make a copy. The Board allowed him to glance at them but refused his request to copy them. They then expressed the opinion that the results in no way satisfied them and the Harrisons would have to submit to a further trial of the watch.

William Harrison was read the Board's resolutions on the matter, which included the grant of an interim payment of £1,500, with a further £1,000 promised on the completion of a second and successful voyage. This amount was to be deducted from any further awards made by the Board up to the limits set by the Act.

William Harrison replied that he accepted a new trial and the watch would be ready in four to five months. However, he was still uneasy over the dispute over the observations. At this point he was interrupted by Nathaniel Bliss (now Astronomer Royal). Bliss said that they had no proof that the watch would answer correctly on a second voyage and they could place no credence on the first voyage's results as the exact longitude of Port Royal, Jamaica, was not known! This astonished William who was convinced that Bliss must be partial only to the method of finding longitude by lunar distances.

Growing Influence of Maskelyne

Mayer had died in March 1762, Bradley also died that same year, and Maskelyne was to publish Mayer's lunar tables himself in 1763. Bliss, Bradley's successor was in poor health when he took up the appointment of Astronomer Royal. It becomes clear from what took place, that Maskelyne was after the job. At a meeting of the Royal Society in 1763, Maskelyne made a forceful statement about the consequences of the Astronomers Royal having regarded the observations made at Greenwich as their own exclusive property. Maskelyne of course, was able to show with his "The British Mariner's Guide" that he was absolutely to be trusted to publish regular reports and useful tables. In fact his principle contribution to science was to be the annual publication of the Nautical Almanac.

This almanac, first published in 1767, contained tables giving the moon's distance from nine other objects, including the sun. Calculated at three hourly intervals for each day of the year, these tables represented a massive computational effort. Each article in the tables was calculated by two persons and checked by a third. This amounts to a total of nearly 30,000 separate calculations for the Lunar tables alone. When combined with other requisite tables, it gives a measure of the cost of producing this new aid to navigation, a cost that the Harrisons insisted should be taken into account.

The Earl of Morton and some other members of the Board of Longitude, insisted that the results obtained by Harrison's watch might be chance. In consequence further stipulations were made, although these were not necessary under the original terms of the Act. These included a full disclosure of the principles of the watch to such persons as the Board saw fit to appoint and the construction of two more watches. The Harrisons protested that none of this was required by the Act, and they were supported by the Earl of Sandwich, First Lord of the Admiralty. (And inventor of the sandwich.) But the Board insisted.

John Harrison had been infuriated by Morton's dismissal of his lifetime of research and experiment, in claiming the results achieved by his timekeeper could be pure chance. In his "Explanation Of My Watch", he thinly veils his contempt for Lord Morton and "Oxford and Cambridge education", and shows that he too, is just as capable of quoting from the scriptures and the classics, as well as devising a mechanism, the understanding of which was beyond members of the Board.

The Board recruited prominent members of the horological industry to examine Harrison's watch in detail, including Thomas Mudge, Alexander Cummings, and William Frodsham. Representatives from France who came over to look at Harrison's watch included Ferdinand Berthoud, whose first "Horloge Marine" was completed in 1763. But the Harrisons insisted on a guarantee of £5,000, before they would reveal details of the watch.

The Trial of 1764

Lord Sandwich intervened in the dispute on the side of John Harrison, and stipulated that he should have a new trial when he pleased. Harrison refused to part with his watch for a trial at Greenwich before the proposed trip to Jamaica. (Did he fear sabotage?). During the drawn-out negotiations for the second trial, Bliss proposed that the expedition should not go to Jamaica, but to some other island. William Harrison reported in his journal:

"***Mr. Harrison then desired if the Board pleased it might be to Antigua, to which Mr. Bliss made answer, No Sir, the Longitude of Antigua is also known; by this Mr. Harrison found that he was not to go to Jamaica because the Longitude was known, and therefore said to Mr. Bliss pray how long has the Longitude of Jamaica been known, to which Mr. Bliss answered a long time.*** (Since 1677 in fact.)

Mr. Harrison then said my fate is very hard that I must not now go to a place because you say the Longitude of it is known, whereas a little time ago you could not give me the Reward because you said the Longitude of that place was not known!"

In March, 1764, William Harrison and a companion, Thomas Wyatt, took the watch, H.4, on HMS Tartar to Barbados. Two official observers went ahead of them on HMS Princess Louisa. They were Charles Green, a professional astronomer, who was to go with Captain James Cook to the Pacific, and the Rev. Nevil Maskelyne, who officiated on the Princess Louisa as ship's chaplain. They were to compare the performance of Harrison's clock against their astronomical observations, at Barbados. Sir John Lindsay, Captain of the Tartar, monitored the going rate of H.4. on its voyage. Everything went well until they reached Barbados on May 15th, and encountered Maskelyne.

"***On Mr. Harrison's landing at Barbados he was told that Mr. Maskelyne was a candidate for the Premium for discovering the Longitude and therefore they thought it was very odd, that he should be sent to make the Observations to judge another's Scheme. Mr. Maskelyne having declared in a very publick manner that he had found the longitude himself and he had also shewn a letter from a Friend in which it was said he was very sorry, that the commissioners should give him the trouble of this second Voyage before they gave him the reward. Therefore it was plain from this that Mr. Maskelyne's Friends were well acquainted with what intention Mr. Maskelyne went to Barbados. Mr. Harrison acquainted Sir John Lindsay with these facts who agreed with Mr. Harrison that this being the case Mr. Maskelyne must certainly be a very improper Person to do the Observations of equal altitudes, according to Mr. Harrison's Instructions from the Board of Longitude."***

"***Therefore the next day when they came to the Observatory Mr. Harrison told Mr. Maskelyne what he had heard & produced Witnesses to what he said, and did insist that Mr. Maskelyne should not Observe, and Sir John Lindsay declared that if Mr. Harrison did insist upon it that he did the same for he did not think it was right that Mr. Maskelyne should, as he could not deny but what Mr. Harrison said was true.***

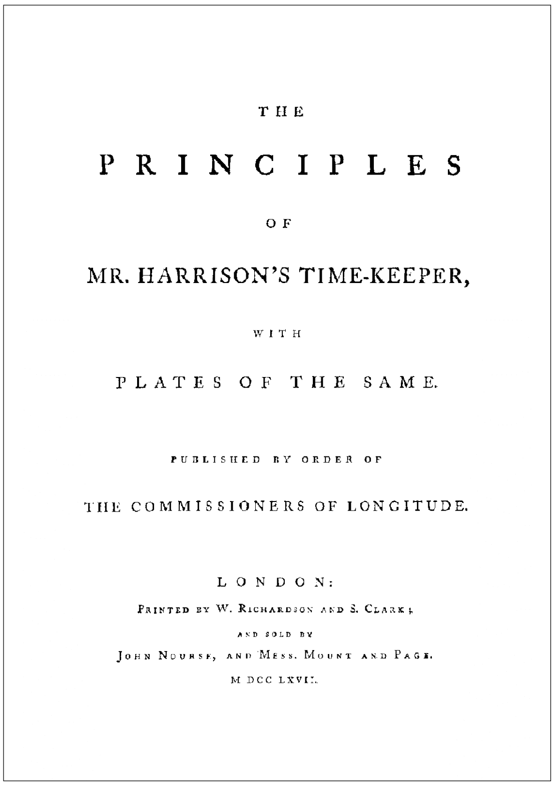
This put Mr. Maskelyne in great confusion and he alleged that if he was not to observe it would be a great dishonour to him, and therefore he insisted upon it he must. After a long time spent in this dispute, Mr. Harrison agreed that Mr. Maskelyne should observe, provided Mr. Green observed the next Observation. Mr. Maskelyne then went to work, but was so confused with the above that his Observations was scarce to be depended upon for every one that were present could see that he sett some his Observations down dubious, where at the same time there was not a cloud near, nor was he in a condition to adjust his Instruments".

It does seem strange that Maskelyne was placed in a position where he might influence the trial of H.4. And it was Maskelyne who had suggested the destination.

The error of H.4., after correction for rate and temperature, amounted to less that one tenth of a second a day. The Board of Longitude declared by a resolution passed on 9th February 1765, that they were "unanimously of opinion that the said timekeeper had kept its time with sufficient correctness". They then saw an Act passed through Parliament which stated that they would pay up to half the reward (the remaining £7,500) if Harrison handed over all his sea-clocks and the full details of H.4.'s mechanism. The Board stipulated that they would not pay the outstanding money unless Harrison made two more of the same timekeepers, although they were well aware that he was now in his seventies. Harrison protested, but to no avail. He started work on two more watches.

Harrison's Clocks Revealed

On 22nd August 1765, a group of six experts came to Harrison's house in Red Lion Square, to see him take the watch apart and explain it fully. The six nominated by the Board of Longitude were: the Rev. John Michell, the Rev. William Ludlam, John Bird the scientific instrument maker, Thomas Mudge who was also working on the development of a chronometer, William Matthews a watchmaker, and Larcum Kendall, who in 1769 made the copy of H.4. which was given to Captain Cook to take on his expeditions to the Pacific. Nevil Maskelyne, now Astronomer Royal, accompanied the six. Their report on Harrison's clock was published.


THE

PRINCIPLES

OF

MR. HARRISON'S TIME-KEEPER,

WITH

PLATES OF THE SAME.

PUBLISHED BY ORDER OF

THE COMMISSIONERS OF LONGITUDE.

LONDON:

Printed by W. Richardson and S. Clark;

and sold by

John Nourse, and Mess. Mount and Page.

M DCC LXVII.

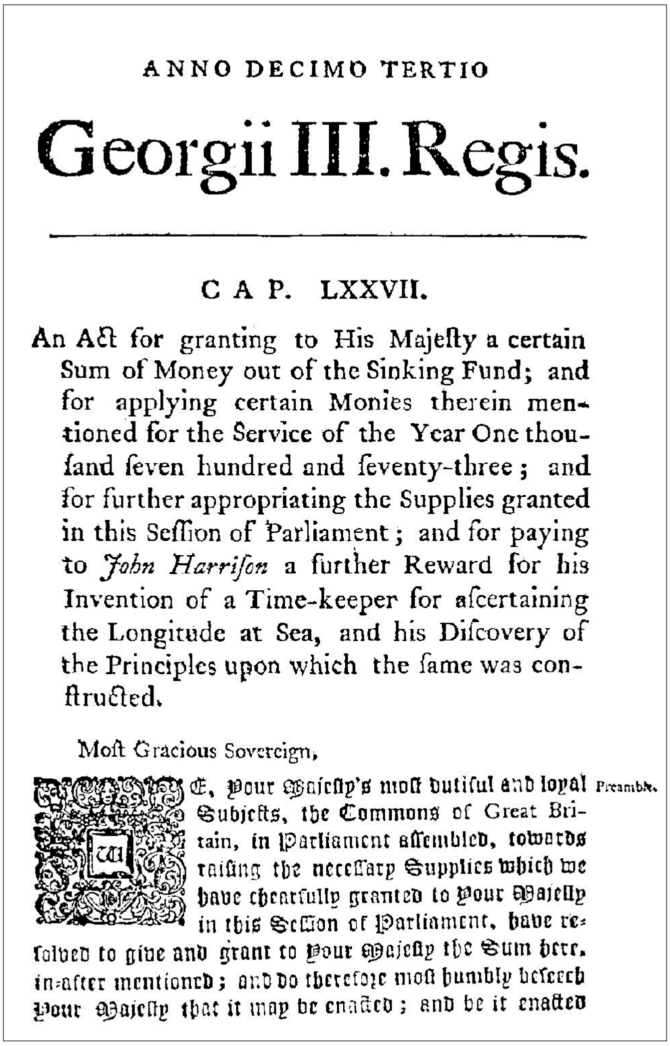
A few months later, on 23rd May 1766, Maskelyne called on Harrison with an order from the Board of Longitude to remove all four sea-clocks to Greenwich to test, although the first three were now only museum pieces. Harrison assumed them to be his and they represented the best part of his life's work. He did not think Maskelyne had any right to take them. The clocks in their cases were extremely heavy. Harrison stood by and let Maskelyne stagger out with each machine to his carriage not even helping when he nearly dropped H.1.

At Greenwich Maskelyne put H.4. through stringent tests devised by himself. Harrison's clocks have remained at Greenwich ever since. Later that year Harrison returned for a long visit to Barrow, his brother James was ill and died in November.

King George III Champions Harrison

Harrison's second watch (H.5.) had been completed in 1770. It is about one inch in diameter smaller than H.4., and without the ornate decoration. Engraved on the back is "No.2 John Harrison and Son, London, 1770". William wrote to Dr. Demainbray telling him about the trouble they had with the Board of Longitude over H.4. Demainbray was Director of King George III's own observatory (the King was interested in science) in the grounds of the King's house at Kew. William asked if Demainbray could test their second watch independently. Demainbury passed the Harrisons' story on to the King who said: "These people have been cruelly wronged". And invited the Harrisons to an audience.

John Harrison and his son had their first audience with the King at Buckingham Palace. William's son later wrote that his grandfather refused to wear the fashionable lace shirts even on such an occasion, but his father went for the latest trends. This went down well with the royal children – one of the little princesses clung to William's hand and would not let go. After hearing their complaints about the Board of Longitude, the King said to John:" By God, Harrison, I'll see you righted."



ANNO DECIMO TERTIO

Georgii III. Regis.

C A P. LXXVII.

An Act for granting to His Majeſty a certain Sum of Money out of the Sinking Fund; and for applying certain Monies therein mentioned for the Service of the Year One thouſand ſeven hundred and ſeventy-three; and for further appropriating the Supplies granted in this Seſſion of Parliament; and for paying to *John Harriſon* a further Reward for his Invention of a Time-keeper for aſcertaining the Longitude at Sea, and his Diſcovery of the Principles upon which the ſame was conſtructed.

Moſt Gracious Sovereign,

WE, Your Majeſty's moſt dutiful and loyal Subjects, the Commons of Great Britain, in Parliament aſſembled, towards raiſing the neceſſary Supplies which we have chearfully granted to Your Majeſty in this Seſſion of Parliament, have reſolved to give and grant to Your Majeſty the Sum herein-after mentioned; and do therefore moſt humbly beſeech Your Majeſty that it may be enacted; and be it enacted Preamble.

The tests at Kew did not go smoothly at first. They had some problems. Stephen Demainbray, the King's astronomer, who was to supervise the tests, had an attack of gout, and was unable to work. William injured his arm, and could not make the journey to Kew. Which left Demainbray's 30 year old son, and King George himself to test the watch. The King wanted the tests to last for ten weeks, four more than the length of the trial stipulated in the Act, to allow no room for doubt. After a bad start which was thought to be caused by the lodestones stored in a cupboard, the total accumulated error on mean time over that period was only four and a half seconds.

The Board of Longitude ignored the results. Harrison petitioned Parliament in 1772, and an investigation was held. By means of a private Bill, the Treasury paid Harrison the remaining £10,000 which the Board of Longitude owed to him.

William Harrison and his son

William Harrison was made a Fellow of the Royal Society in 1765. In 1766, he married for the second time, Susannah Hodgson. After 1773, he was a wealthy man of some importance. He had charitable and educational interests in the area and was a Governor of the Foundling Hospital.

William Harrison returned to Barrow when his parents died. He purchased the Holywell Cotton Twist Company in Flintshire in Wales, and in 1791 he was made High Sheriff of Monmouthshire, although he was living in Barrow with his third wife and their daughter Ann by then. His son John married a girl from Edinburgh, Jane Fenwick and they kept a pub which was near Grimsby, until retiring to Hull. John wrote a book about his famous grandfather but only chapters 13 to 17 were eventually published under the mystifying title "A trait in the Character of King George III" and the pseudonym "Johan Horrins". This gives the impression there was material other members of the family did not want publicised. A copy is in the library of the British Horological Institute.

Recognition of Harrison's Work

John Harrison had recommended Larcum Kendall to make a copy of H.4. in 1769. This is now referred to as K.1. It is an exact replica, even to the decorative work. This design was too expensive to be commercially viable and Kendall's further chronometers, K.2., and K.3., made in 1772 and 1774 were Kendall's own designs, and much cheaper at £200 and £100. By the 1770s many French and British clockmakers were producing successful chronometers. Those of John Arnold had the advantage of being considerably cheaper than those by Kendall, at 60 guineas each, although they proved less reliable than K.1.

Maskelyne published the first of the annual editions of The Nautical Almanac in 1766 for the year 1767. He also published "Tables Requisite to be Used with the Astronomical and Nautical Ephemeris". In 1772, the Board published "Tables for Correcting the apparent Distance of the Moon and a star from the Effects of Refraction and Parallax" as an aid to this method, with a preface by one of the members of the Board.

Shepherd was Plumian Professor of Astronomy, Cambridge University, and Master of Mechanics to His Majesty. John Harrison mentions him in his book Concerning Such Mechanism. He was writing about the problems of explaining his timekeeper to the Board of Longitude and says "For in particular, I took some Pains with Mr. Shepherd, [viz. when he was my Friend] but could make nothing of him, [viz. any farther than that one Wheel turned another] although it was at his Desire."

Certainly Shepherd and Harrison had fallen out, for in his preface Professor Shepherd writes:

"In 1726, Mr. *John Harrison*, famous for his Time-keepers, began to apply his Thoughts entirely to the Construction of them. The three first Machines he made are now deposited at the Royal Observatory at Greenwich, and likewise his Watch, which has been tried in two voyages at Sea; the first in 1761 to Jamaica; the second to Barbados in 1764. It did not appear by these Trials sufficiently exact to answer what was required by the Act of the Twelfth of *Queen Anne*: and the Trial that has been made of it since by the *Astronomer Royal,* confirms the Judgment formed of it by the *Commissioners of Longitude."*

This is an astonishing statement as Shepherd signed the certificate given to John Harrison after the 1764 trial which stated that the watch had exceeded the requirements of the Act. In effect it was a clear direction to the potential customers that nautical timekeepers had been found wanting and should not therefore be considered a reliable method. There can be no doubt that the Lunar faction put back the general use of the chronometer at sea by 30 years. However Shepherd continued:

"Some other Watches have been made since Mr. *Harrison's*, one on his, and the others on different Constructions, which will be tried in an Expedition that is preparing for the South Seas under the Direction of Captain *Cook* of the *Resolution Sloop of War,* for the Improvement of Navigation and Geography....."

Captain James Cook was to try out both the lunar distances and the chronometers on his expedition to the Pacific in 1772. The chronometers taken with, were Larcum Kendall's copy of H.4. - K.1., and three chronometers by John Arnold. On his return in 1775, Cook wrote to the Secretary of the Admiralty:

"Mr. Kendall's Watch (which cost £450) exceeded the expectations of its most zealous advocate and by being now and then corrected by lunar observations has been our faithful guide through all vicissitudes of climates."

Cook took K.1. with him on his third expedition to the Pacific. Soon after Cook was murdered, K.1 stopped. The balance spring had broken. It was repaired by a Russian clockmaker in the port of Petropavlosk, Kamchatka. They were able to use it to find their way home. Then K.1. was overhauled at the request of Greenwich by Thomas Earnshaw and sent back to the North Pacific with Vancouver.

More Action Against Chronometers

In 1774, a new Act was passed for the Board of Longitude in Parliament which repealed the Act of 1714, and imposed new tougher conditions for an award which would make it virtually impossible for a timekeeper to comply with success. The Act was largely drafted by Maskelyne who remarked that he:

"had given the Mechanics a bone that would crack their teeth!"

When Thomas Mudge appealed to Parliament, the committee appointed to deal with the matter commented in its report:

"The present Act does indeed impose conditions so difficult, and so impossible to be surmounted, if enforced to the full extent of which they are capable that it is to be feared few artists will quit the certain gains of their profession, to enter into things so discouraging and precarious."

Mudge was awarded £2,500 from Parliament, despite the opposition of the Board of Longitude. Mudge's struggle with the Board of Longitude and Maskelyne, like Harrison's, lasted a lifetime. Thomas Earnshaw too, had a lifelong battle with the Board to win the appropriate award for his chronometers. In 1802 Earnshaw finally succeeded in getting Maskelyne's much criticized method of testing the chronometers changed. By the 1820s, chronometers were supplied to most fleets. Although ship's officers were still expected to learn the lunar distance method it became rarely used.

Harrison sums up his experiences in his book.

In 1775, when he was 82, John Harrison wrote up a final account of his life's work in which he also made clear his opinion of the Board of Longitude.
He died the following year on 24th March 1776.

A
DESCRIPTION
CONCERNING
SUCH MECHANISM
AS WILL AFFORD A NICE, OR TRUE
MENSURATION OF TIME;
TOGETHER WITH
SOME ACCOUNT
OF THE
ATTEMPTS for the DISCOVERY
OF THE
LONGITUDE BY THE MOON:
AS ALSO
AN ACCOUNT
OF THE
DISCOVERY
OF THE
SCALE OF MUSICK.

By JOHN HARRISON,
INVENTER of the TIME-KEEPER for the LONGITUDE at SEA.

LONDON:
Printed for the AUTHOR, and fold by T. JONES,
No. 138 FETTER LANE,

MDCCLXXV

the Longitude] * and, I think, all ought to be pleaſed, in that it hath ſo pleaſed God that I have had ſuch Length of Life, &c. wherein to bring ſo noble and uſeful a Thing to ſuch great Perfection, yea, even to nearly the Truth itſelf; † but ſtill the Profeſſors or Prieſts as above] muſt abſurdly think, that the Money would be better to them, than this [or ſuch Things as mine] can be to the Nation, for they wanted ſo to influence the Parliamenr, as to have my Money, notwithſtanding what the Watch had done! ‡ And now I am ſure, from my

* But here it may be noted, that what will ſometimes render an Obſervation in this Caſe to be 2 or 3 Miles wrong, will or may by the Moon make it as many Degrees wrong, viz. Refraction was parallax, &c. not to be intermingled.

† But it is to be underſtood, that to get ſuch a Longitude-Watch adjuſted, viz. to what it will be capable of bearing, is not to be done [in any reaſonable Time] by one or more of Mr. Graham's Clocks, nor indeed from or by any Obſervation whatever, ſave only, as by or from the Performance of ſuch a Clock as mine; conſequently any proper Place, or proper Places ſo furniſhed, viz. with ſuch a Piece or Pieces of Furniture, muſt, where properly wanted, be of very great Utility indeed; yea, certainly, far to ſurpaſs in Uſefulneſs, or Highneſs of Uſe, all other Obſervatories in the World.

‡ But what muſt theſe men be ſaid to be done by, when the Thing was done [viz. ſo far as to fulfil the Act of Parliament] before they began? and that in the beſt Manner that was, or is in Nature ever to be wiſhed for, but as notwithſtanding, would not let it, viz. as in the

my laſt Improvement, that by or from the Performance of a Watch of ſuch a Size as may be bore with in the Pocket, [but I ſhould not adviſe for it always to be kept there]—the Longitude may be had, and that to a much greater Certainty or Exactneſs, as well as with far more Eaſe and Frequency, than ever it will, or can be, by the Moon, conſequently the more by far to be relied upon.

Now, in the former Part of this Book I have treated about Matters pertaining to the Strictneſs of meaſuring Time, and have ſhewn the Deficiencies of ſuch Means as Mr. Graham had taken or made Uſe of for that Purpoſe; and I have alſo treated of the improper, troubleſome, erroneous—tedious Method, which the Profeſſors at Cambridge and Oxford would have to be for the Longitude at Sea: And now I am about to treat of another Concern, the which happened to

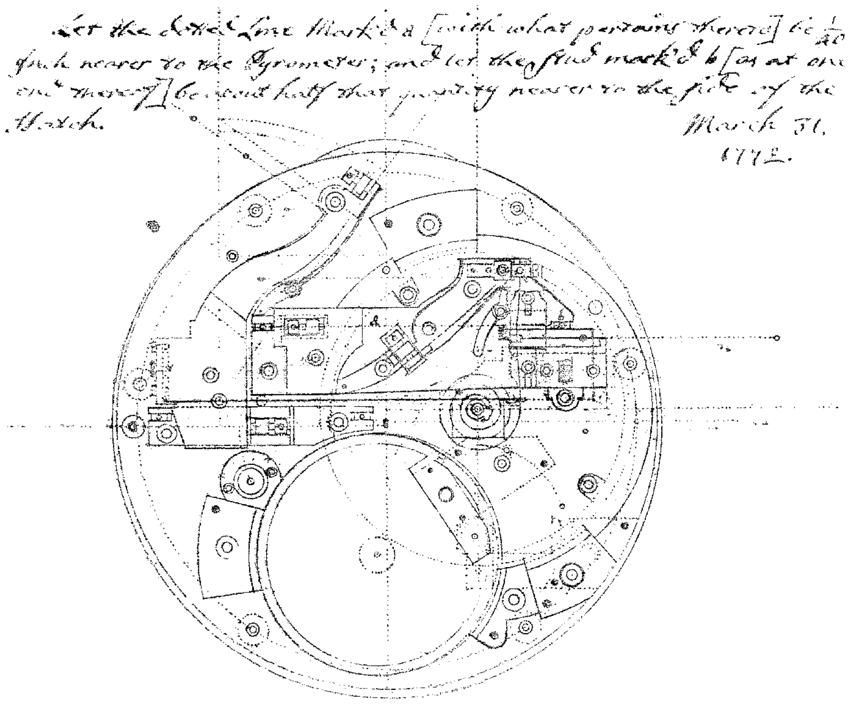
F fall

the whole be paid for, but thought it the more proper to rob the Proprietor of Half his Wages. Whiſton was piſſed on, and Ditton ſhit on, but ſurely theſe Men ought to be beſmear'd or beſpatter'd with both, who, after the Longitude was had by a good and eaſy Way, wanted to have it from a very troubleſome, tedious, difficult, and uncertain endleſs Method! or rather as from uncertain endleſs Methods! For, beſides as from the Moon, from Jupiter's Satellites, the which, as with Reſpect to our needful Purpoſe of Longitude, are not worth mentioning; but ſtill, or as notwithſtanding, they certainly muſt, by the Hand of Providence, be Highly Created, as well as the Moon, for ſomething elſe; and therefore they ſhould rather have told us—for what,

The Mystery of H5:

Harrison was asked to make two more clocks, after H.4. One, H.5., was tested by King George III, the other has vanished. We know that Harrison made it. He mentions it in his book.

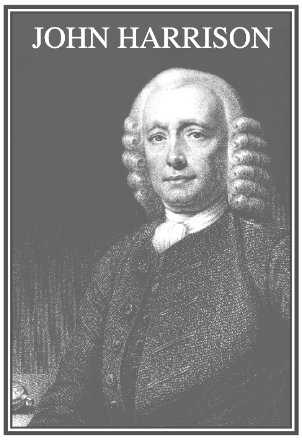
"Now, from Experience, I can make bold to say, that my Watch (or Time-Keeper for the Longitude) will come up to 1 Second in a Fortnight, viz. as when my last Piece of Improvement, and as with a little Alteration, viz. so as whereby to receive it, is put in Execution, the which I described in Drawings in the latter End of the Year of our Lord 1772, and as then in the 80th Year of my Age; and surely it ought to be looked upon as an Age well spent...."



William probably took it back to Humberside, along with the drawings, some of which have survived. A small section from some very old photocopies of even older reproductions which were given to Mervyn Hobden by Colonel Quill, is reconstructed above. It came into the hands of a jeweller, Herman Busch (later Bush) of 14 Mytongate, Hessle, who described it in a letter to the Horological Journal November 1885. The mechanism had been made from brass and other metal alloys, and "specially prepared wood" was used for the arms of the balance. This shop was sold soon after to a tripe butcher, and Mytongate, like much of Hull, was heavily bombed in World War II. Colonel Quill had been offered the charred remains of the Jeffrey's watch which had been in a safe in another bombed out jewellers shop in Hull.

Also missing are the remaining pages and notes for William Harrison's son's book, which members of his family apparently, did not want published. His son, an engineer, who lived at 31 Spring Street, Hull, never married and left these papers to a friend when he died. Somewhere - there may still be some papers, drawings, his grandson's missing manuscript, which disappeared after it was sold in 1912, and the missing H.6. Harrison's last work.

Acknowledgements



This book was originally produced to accompany the Harrison Event in the Usher Gallery, Lincoln, August 1988, arranged by the Lincolnshire Branch of the British Horological Institute, with the Lincoln Astronomical Society, and the WEA. The National Maritime Museum, Greenwich, and its chief curator Beresford Hutchinson gave permission for illustrations of Harrison’s clocks to be used. The main display was by Mervyn Hobden and Edge Parnaby, helped by Heather Hobden with the story-line and most of the text, and John Ablott on James Harrison and his family and their clocks, Arthur Credland on 18th century Hull, Harry Middleton on the astronomical methods of finding longitude, who contributed many of the illustrations on finding longitude in this book. Mike Lincoln provided the portrait of Harrison, and copies for sale, (later reproduced on the teatowel). The musicians playing music using Harrison’s music scale - were organised by Charles Lucy and included Damian Law. And many others contributed also. After the success of the Harrison Event, others saw the potential in Harrison's story for seminars, films and books.

Mervyn Hobden had founded the Harrison Research Group in the early 1970s – to bring together anyone researching aspects of Harrison's scientific work. Much of the original material on Harrison's work, had already been researched by Mervyn Hobden, at the RGO, Herstmonceaux, (where he worked in the early 1970's in the chronometer section, at the time the Harrison clocks were there), the Guildhall Library London, in Barrow, and with help from Colonel Quill, Jack Martin (in Barrow-on-Humber) and many others. The authors were helped further by many people in Barrow-on-Humber, including Miss Dora Borrill who was Lord of the Manor. Derek Howse gave us useful feedback. Ivan Slee told us about Watcombe. The 3rd Edition became a source of reference for writers including Dava Sobel, and producers. Yorkshire Television, used the 3rd edition in their series Local Heroes, 13th July 1992. BBC Radio Edinburgh used the 3rd edition to assist in their programme on Harrison.

A number of other writers used the 3rd edition as source material, including writers in the USA and Australia. The John Harrison School in Barrow-on-Humber made use of the original exhibition material as part of their celebrations of Harrison’s 300th birthday, with excellent and impressive work by the 5 to 11 year old pupils. The exhibition material has also been used by Scunthorpe Museum.

At Foulby, John Austerfield gave us information helpful in constructing John Harrison’s first years. Science historian, Allan Chapman gave us interesting insight into the career and motivations of Bradley, and Australian playwright James Rowntree told us Henry Harrison's house in Barrow-on-Humber was for sale when he was over here researching for his play on Harrison, so we were able to look over it and reconstruct with the help of neighbours, its 18th century layout. The 1997 edition was used as reference for a BBC2 Horizon special and a film.

Feedback has always included a request for more technical information so a separate book is now being prepared by Mervyn Hobden. More information depending on the requirements of the audience is provided at the talks given by Mervyn and Heather Hobden. Sadly the tea-towel illustrated (commissioned from Impsport) is not longer available.

Further Reading

Gould: R., The Marine Chronometer, London, 1923.
Howse: D., Greenwich Time and the Discovery of the Longitude, Oxford, 1980.
Hutson: A.B.A., The Navigator's Art, London, 1974.
Laycock: W., The Lost Science of John "Longitude" Harrison, London, 1976.
Quill: H., John Harrison the Man who Found Longitude, 1966.
Waters: D.W., The Art of Navigation in England in Elizabethan and Early Stuart Times, 1978

The British Horological Institute, Upton Hall, Nottinghamshire, is a good starting point for anyone wanting to find out more about John Harrison. The staff can put enquirers in touch with those members who can answer detailed queries on Harrison's work, including those who have reconstructed his clocks. The Library contains Harrison's own books, pamphlets and other relevant books and papers, plus the past copies of The Horological Journal, with all the articles and letters discussing Harrison's science. A list is provided on their website. The Hull Town Docks Museum can provide further information on the Harrisons, their work, and Humberside in the 18th century. Local historians in Barrow have collected material. Two useful books are: "Barrow on Humber" published by Joyce Martin, 1988, and "John Harrison's Village" published by the WEA, 1999. The Central Library in Lincoln has material referring to Harrison for reference. In London, the Guildhall Library and Museum has some original drawings and H.5., and the National Maritime Museum has H.1., H.2., H.3., H.4., & K.1., on display.

Further enquiries are welcome. You may contact Mervyn and Heather Hobden through our website: http://www.cosmicelk.net, or email: mail@cosmicelk.net.

Harrison's work on music

Harrison's scale of music has been studied for many years by **Charles Lucy** and full information and contact details can be found on his website: http://www.lucytune.com/.

Harrison's Place in History

Harrison's dispute with the Board of Longitude, made him a legendary figure. And has caused his real background to be misinterpreted and his contribution as a scientist to be overlooked. John Harrison and his brother were part of the "Industrial Revolution". It was a social revolution too, forming a new middle class of skilled professional people (of which the Harrisons were typical) that were in a position to despise and resent the traditional aristocracy and clergy, and demand more political power. Harrison's contempt of the "priests and scholars" (of which Maskelyne was very much a representative) made him a symbol of the new attitude to the traditional establishment. Their contempt in return for "mechanics" was tinged with fear – which turned out to be justified – especially in France. Harrison died just before the French Revolution.

Harrison's Scientific Work

In recent years there has been a lot of research by several people into Harrison's scientific work and its implications. This can now be found in a number of papers, articles and a new summary by Mervyn Hobden is to be published as part 2 of this book.

Concerning Such Mechanism

Gnarled hands now, can barely grip the pen
Pain stiff in every joint that moved so free.
Age's damned burden moving to constrain my eyes
Yet still I brightly see.
That vital spark hid deep within the brain
As if the great balances beat across the room
Bringing my heart each second full again.
Aye, that one must cease its patient measure soon.

Beat then my life away, good friends
For well I wrought you with these very hands.
The patient graver biting into steel
And brass poured hot and smoking into sand.
Strange work for a carpenter to fill.
Yet difference is there then, twixt wood and brass
Shaped by the fingers' careful skill.
Not in that burning image that won't pass
Out of my mind.
I moved those very fingers with my Soul.
Lord, how those balances beat behind my brain
Driving me on each second to my goal.

Well may the many fools and priests cavort.
As well they might that lack that precious art
To see such mysteries of a plainer sort
Than common fancy can to them impart.
A long hard road for any man to take.
Nay, but there's not one step I would retract
Nor second's success for an hour's mistake exchange,
Or find soft words to modify my tact.
As to reward, well look you on these things
That I have made and let your fancy ask
Given the self-same measure to complete
Such beauty.
What is one lifetime set to such a task.

Contents

John Harrison
and the Problem of Longitude

☞ **What were the problems of finding longitude at sea**

☞ **How did John Harrison,**
the clockmaker from Barrow-on-Humber, help solve them

☞ **Why did he have such a long struggle to get recognition for his scientific achievements**

New Edition with latest updates.

Price £5

The Cosmic Elk
ISBN -13: 978-1871443-16-5

9 781871 443165 >