Positioning: A Brief History

Learning Objectives

In this lecture you will learn…

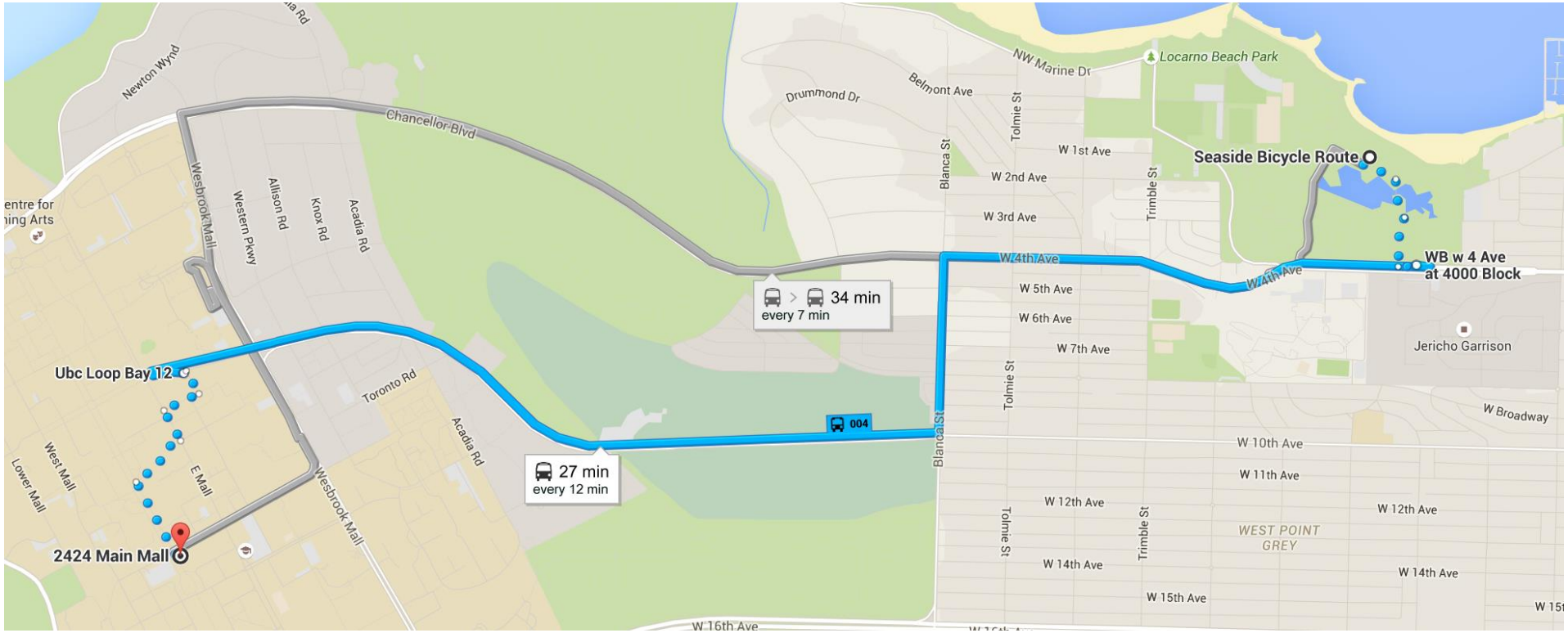
- Why positioning was important in the past and why it's still important today
- How the concepts of positioning have developed through time and have resulted in the technology we currently use
- Principles behind the space technology we currently use today to locate ourselves

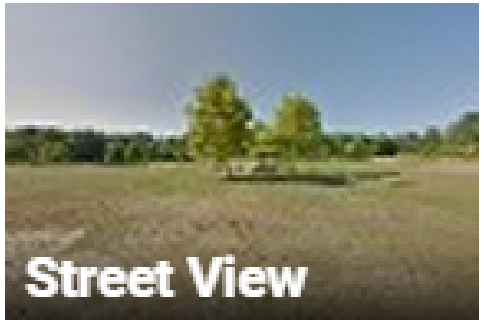
Introduction and Definitions

A position can be determined in two different ways:

- Relative
  - To other landmarks or features
- Absolute
  - Coordinates of a point in space

To obtain an absolute position requires sophisticated equipment and precise measurements





Jericho Beach Park, 3941 Point ...

Vancouver, BC V6R 4L9

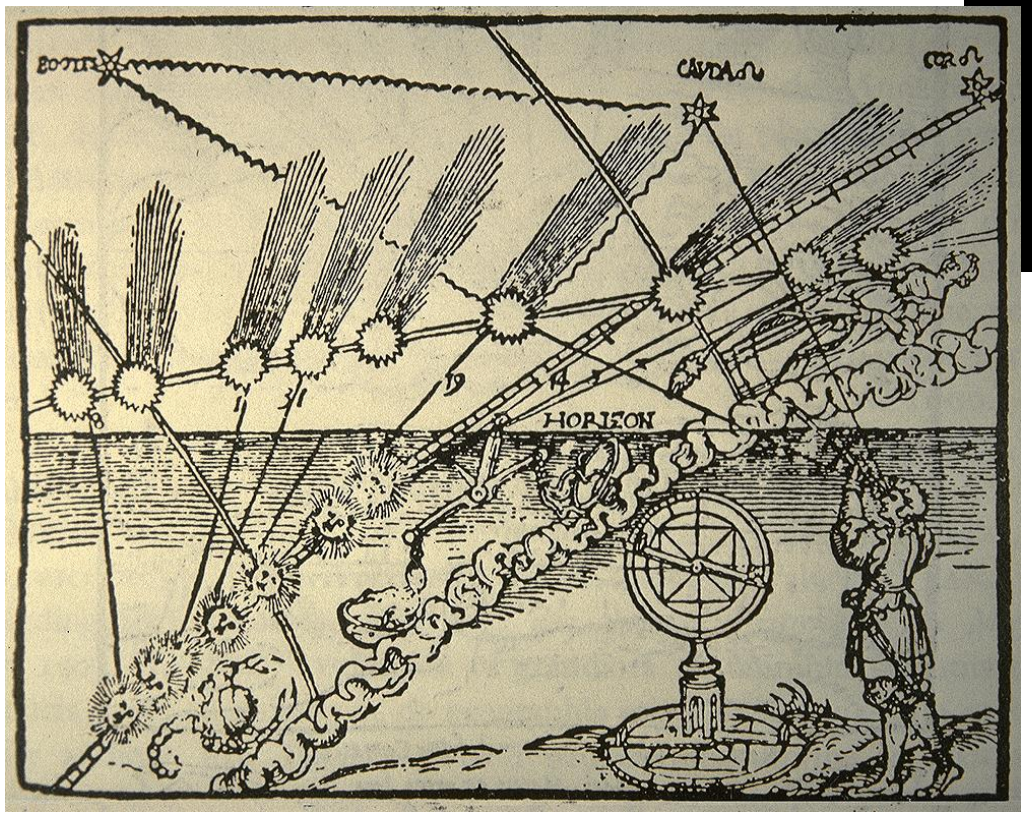
49.272179, -123.196654

Jericho beach position: relative versus absolute positioning @ Googlemaps

Which definition is absolute and which is relative ?

Positioning in the Pre-Space Era

- Astronomy, navigation, surveying and geodesy were based on similar instruments and methods
- Historically, the most important practical application of positioning was to provide safe ocean navigation



Triangulation to measure a comet trajectory, 1532
@ Wikimedia Commons

Triangulation

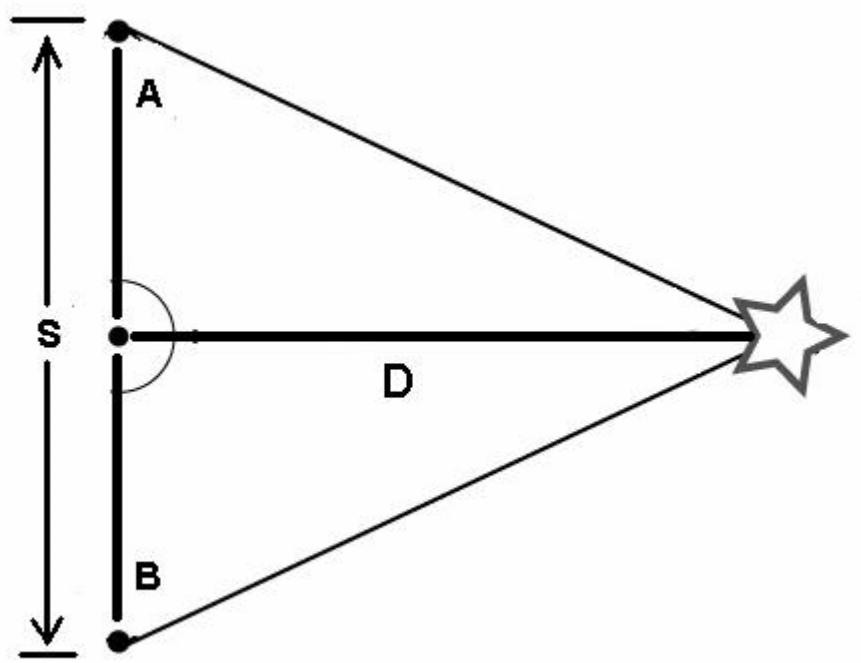
Based on the trigonometric rule that if one side and two angles of a triangle are known, the remaining sides can be computed

By measuring

- Angles – triangulation
- Distances – trilateration

Imagine a distant mountain peak (the star) and two observers are located at 'A' and 'B' separated by a few kilometers (the length 'S').

The base angles at A and B can be measured with an instrument called a theodolite. By knowing the base distance A to B, and the angles the distance to the peak can be worked out using triangulation.

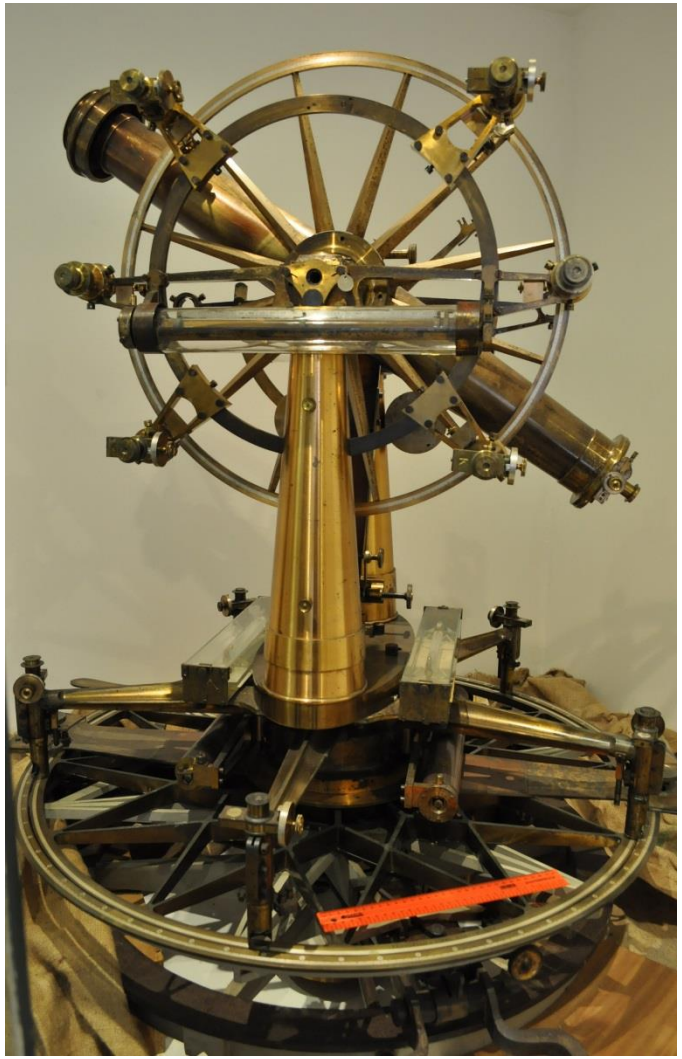


Triangulation
@ Spacemath, NASA

Measuring Angles: Theodolites

Theodolite

- surveying instrument of high precision
- measure both vertical and horizontal angles



Theodolite, 1860
@ Wikimedia Commons

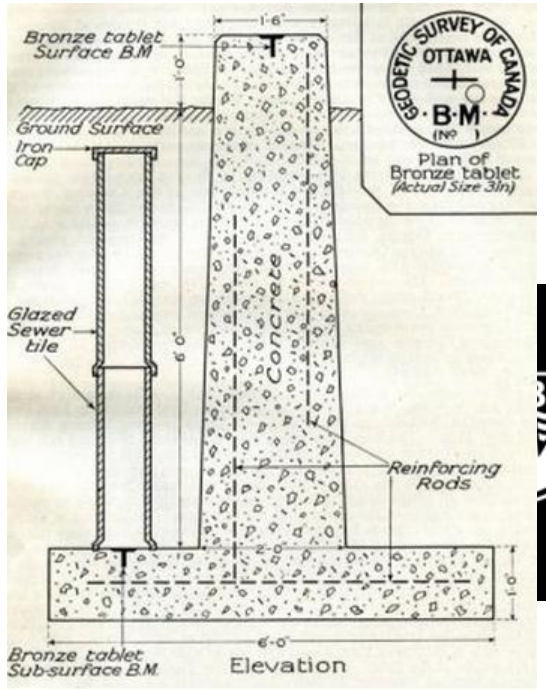
Geodetic network

- The first geodetic survey was undertaken in France at the end of the 17th and early 18th century
- By the end of the 19th century, major geodetic networks covered the United States, Canada, India, Great Britain, and large parts of Europe

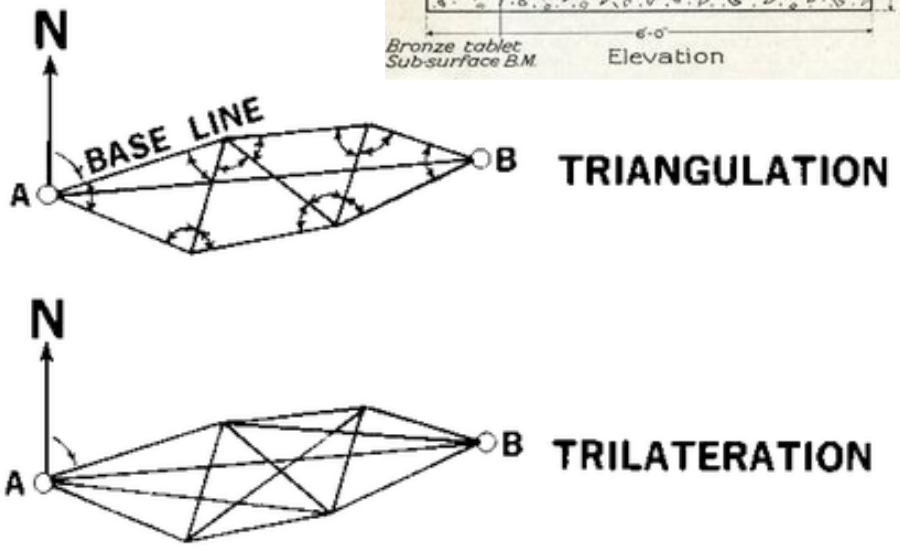
Nautical chart of the Atlantic Ocean, 1693
@ Wikimedia Commons

Geodetic network

- The geodetic points are the historical basis for the mapping of the Earth's surface
- It provides a number of fixed stations whose relative and absolute positions are accurately established
- These points can then be used to calculate other points by using triangulation



Geodetic point @ Wikimedia Commons



Triangulation versus trilateration @ Wikimedia Commons

Barry Davidson

- 9 years in jail if you tamper with them

Geodetic network in Poland

Geodetic point in US
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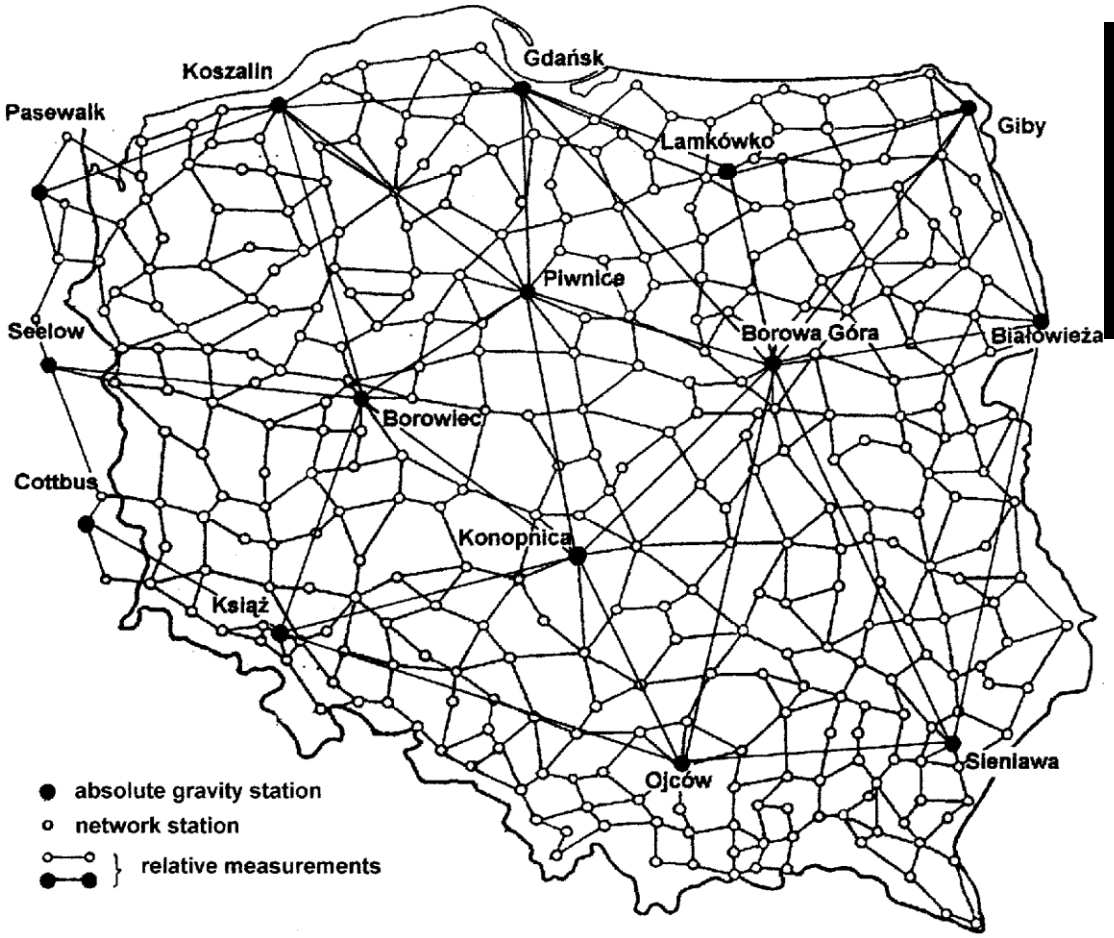


Geodetic network in Poland
@ Geodezja

Ocean navigation

- Navigation on the ocean was very problematic
- Navigation methods using

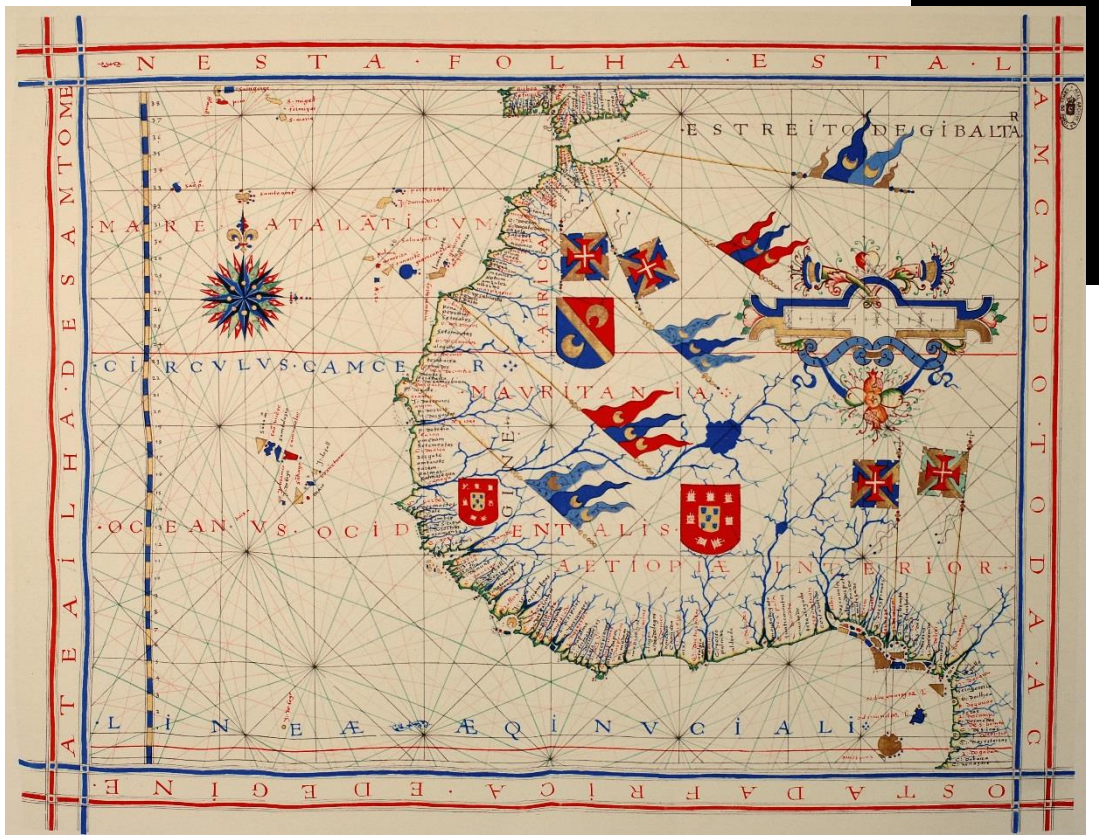
  Relative positioning:
  - Pilotage
  - Dead reckoning

  Absolute positioning:
  - Celestial navigation & marine chronometer

The Noord-Nieuwland in Table Bay, 1762
@ Wikimedia Commons

Pilotage

- First method of navigation used
- Before 15th century or in coastal navigation, within sight of land
- Based on visual triangulation to known landmarks
- No need for accurate position, but that one is in a safe position or on a safe line
- Generally helped by maps or nautical charts



Nautical chart of Fernao Vaz Dourado, 1571
@ Wikimedia Commons

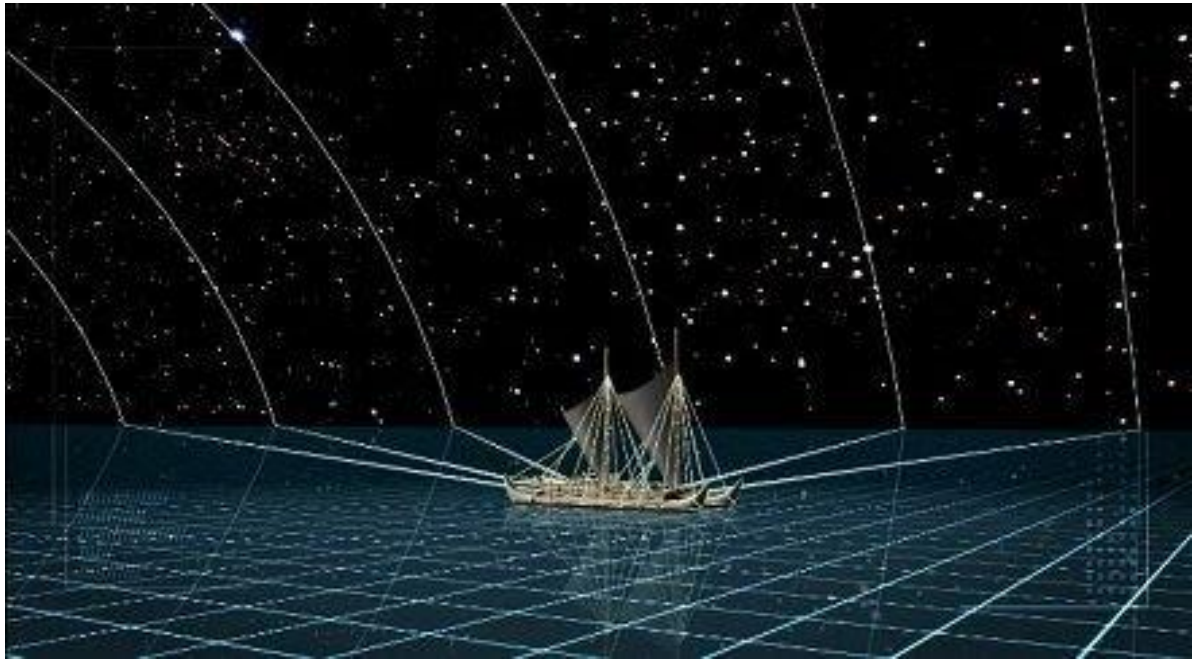
Dead Reckoning

- First method of navigating on the *open* sea
- Used from 15th to 17th Century
- Calculate position by using a previously determined position, and advancing that position based upon estimated speed over time
- Fairly accurate at short distances
- Requires very precise information on speed and direction over long distances -> cumulative errors

Pedro Alvares Cabra discovery of Brazil, 1500
@ Wikimedia Commons

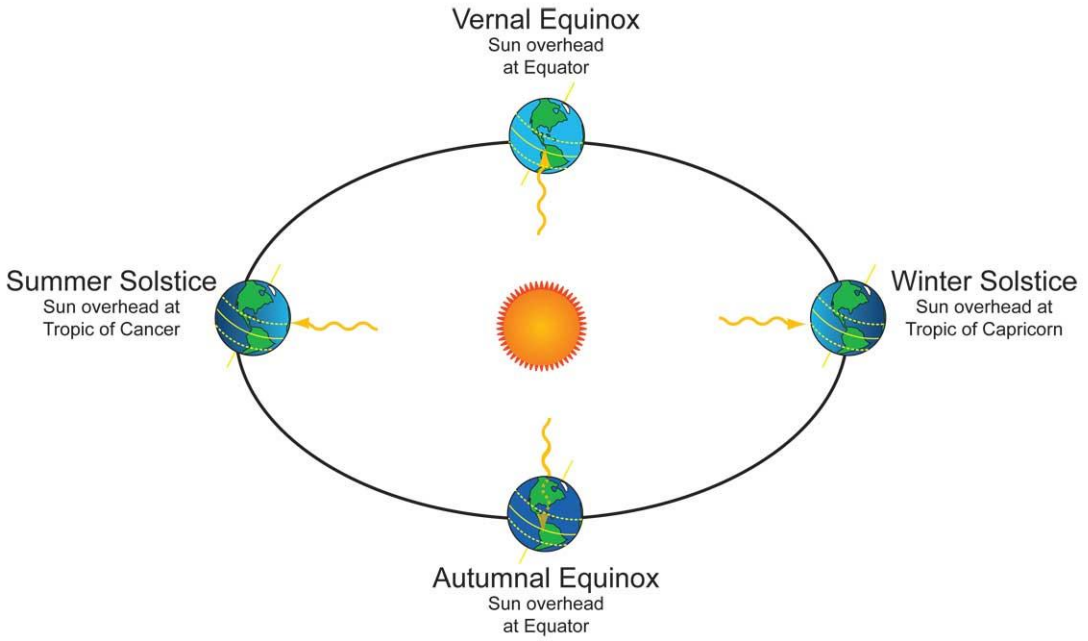
Celestial Navigation

- Dead reckoning errors accumulate over long voyages
- So navigators sought other reference points on the sea
- Most found that:
  - Part of the solution was in the sky
  - While part of the solution relied upon time



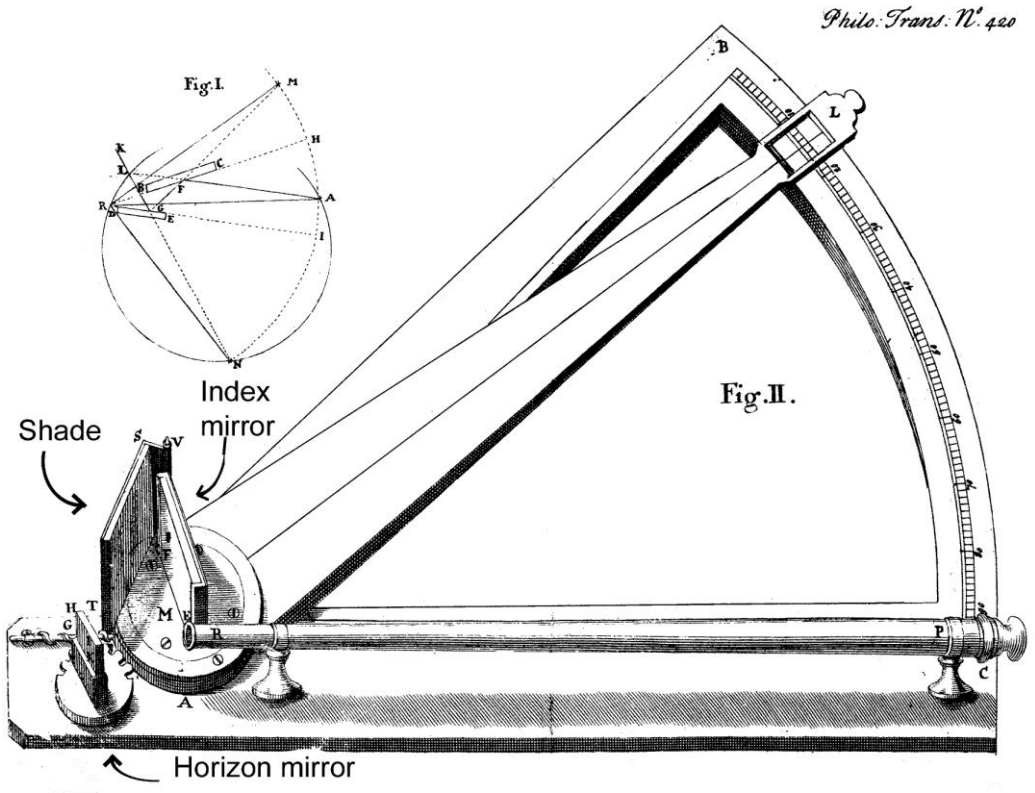
Calculating Latitude

- The night sky changes for most of us on a daily and seasonal scale
  - The daily rotation of the Earth causes stars to sweep through the sky
  - The seasonal revolution of the Earth around the sun changes our perspective
    - i.e. The direction you face during night time changes



Estimating Latitude

- To measure latitude we can point to:
  - North star in northern hemisphere
- The North Star is nearly directly above the north pole
  - No matter what time of year or day, the North star is always directly above the north pole
- The angle to the North Star directly measures your latitude



Quadrant description
@ Wikimedia Commons

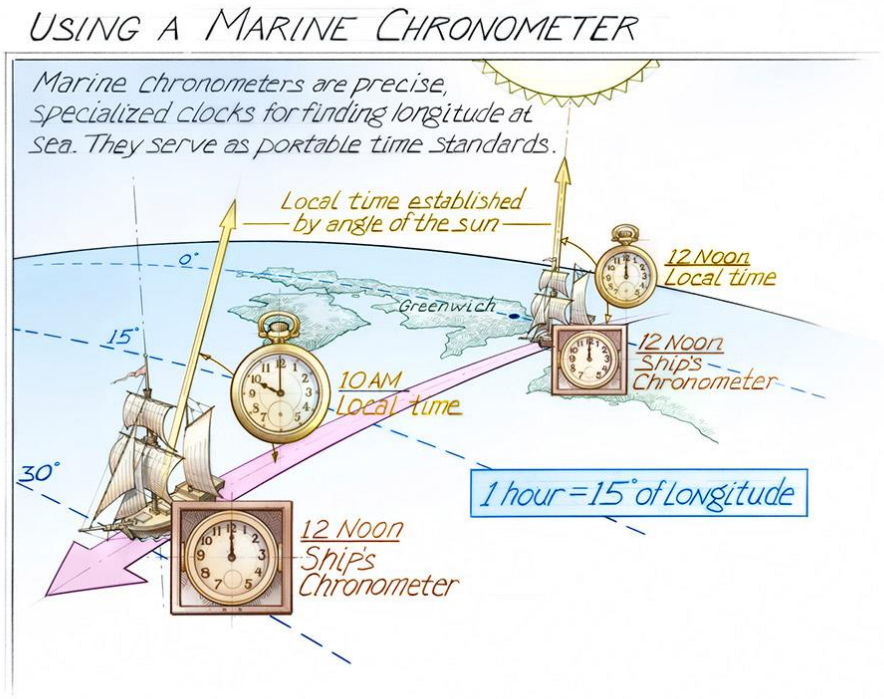
Longitude Challenge

- Longitude was much harder
- And resulted in many ship wreaks
- For decades no one was able to come up with a practical solution to the problem
- Some searched for the solution in the skies, others in building a precise clock…

Ships in Distress off a Rocky Coast, 1667
@ National Gallery of Art, Washington

The Longitude Challenge

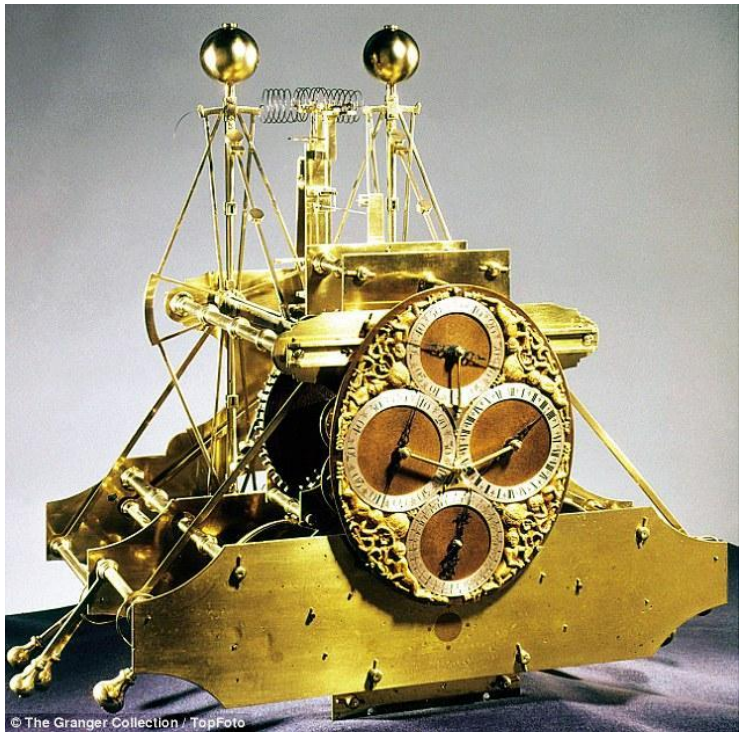
- The key to calculating longitude is time
- The distance from a line of longitude to the prime meridian can be measured in hours and minutes
- The Earth revolves once on its axis every 24 hours at the equivalent of 1° of longitude in four minutes, or 15° an hour
- The comparison of time between a known place (e.g. Greenwich) and the local time would determine longitude
  - Note the graphic on the right here denotes “local time” as the mean Greenwich time

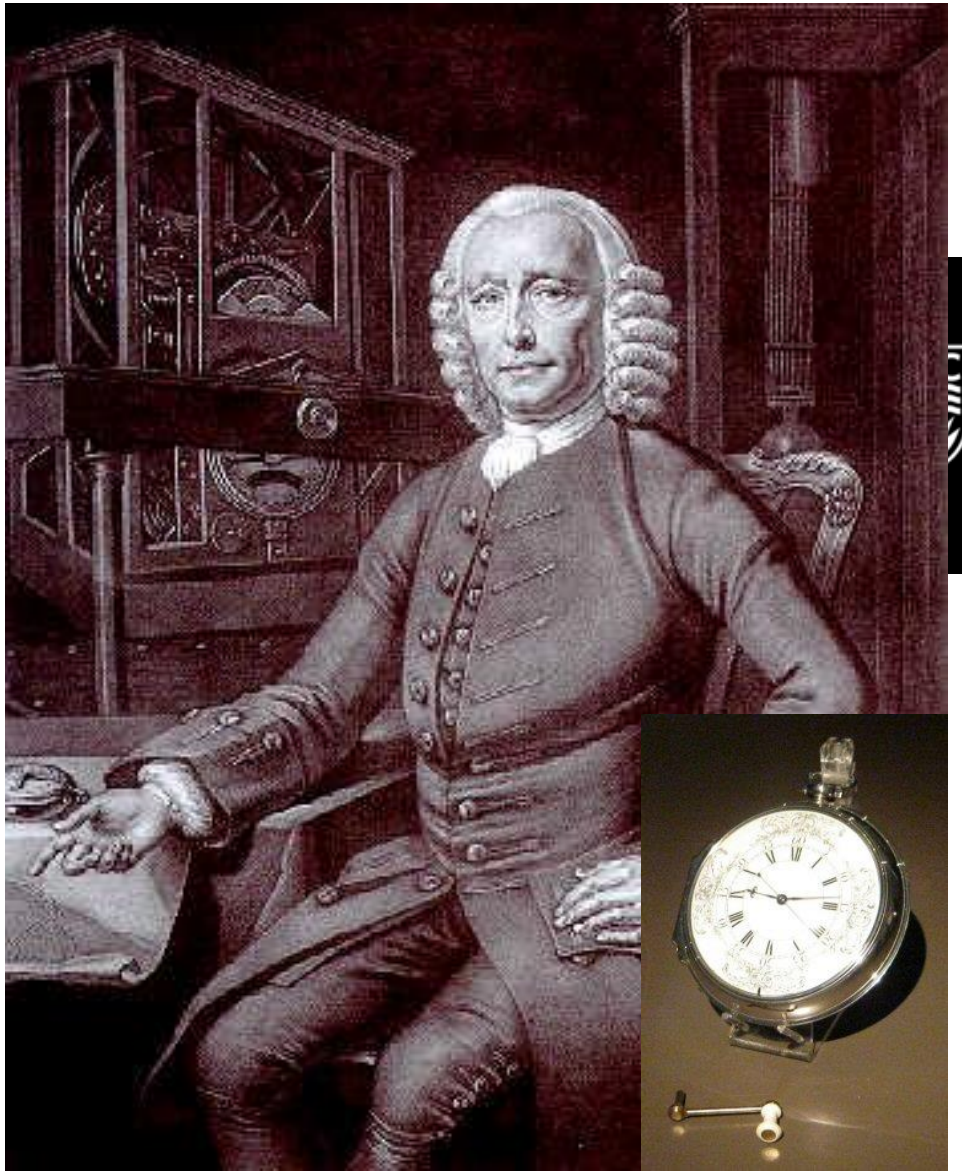


Calculating longitude with a marine chronometer
@ National Air and Space Museum, Smithsonian Institution

The Marine Chronometer

- John Harrison came up with his H4 chronometer design in 1761





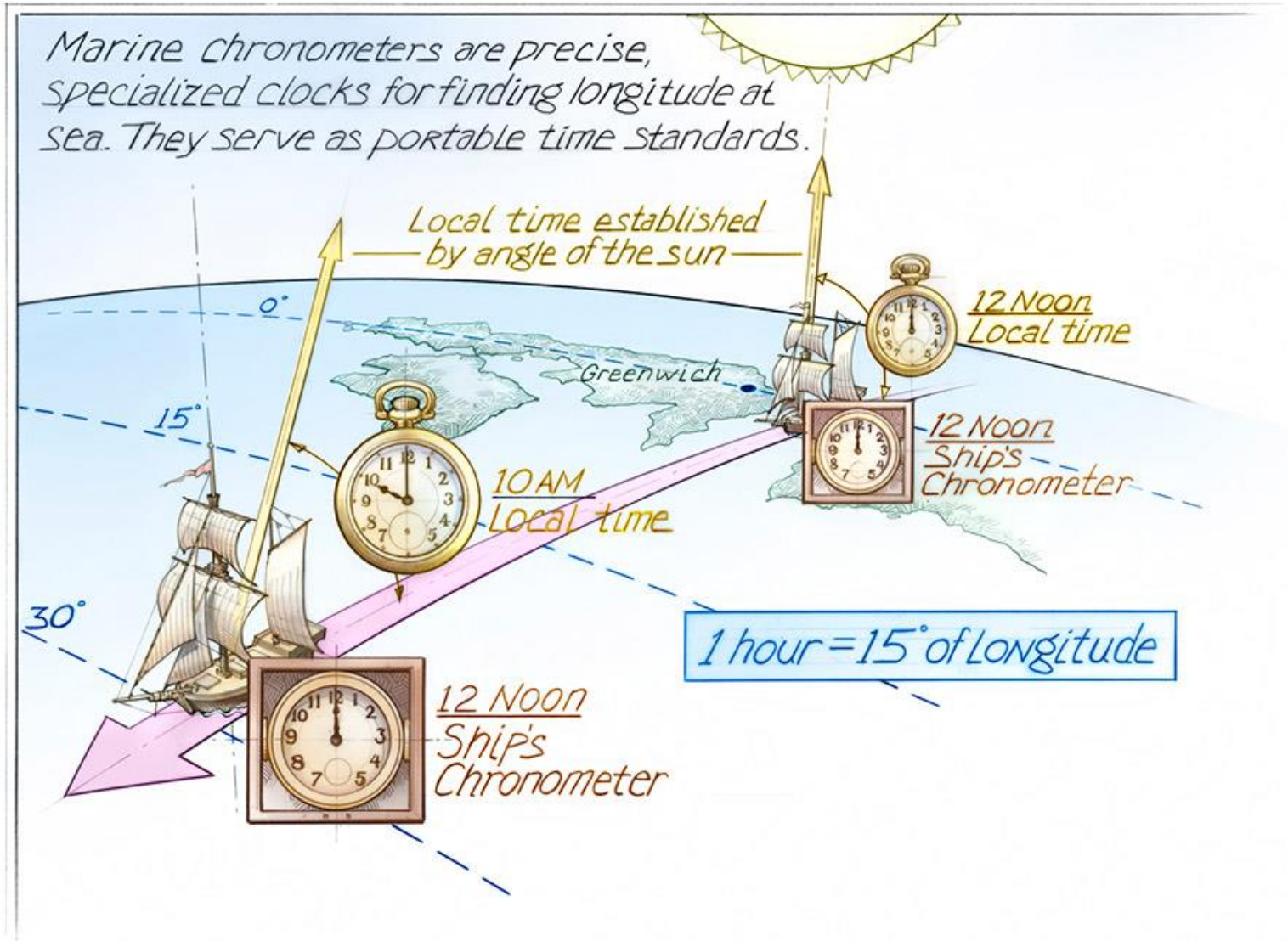
John Harrison, 1767
@ Wikimedia Commons

The Marine Chronometer

- Requires that an observer knows exact Greenwich Mean Time (GMT) at the moment of observation
- Every four seconds of time error, the position measurement will be off by approximately one nautical mile

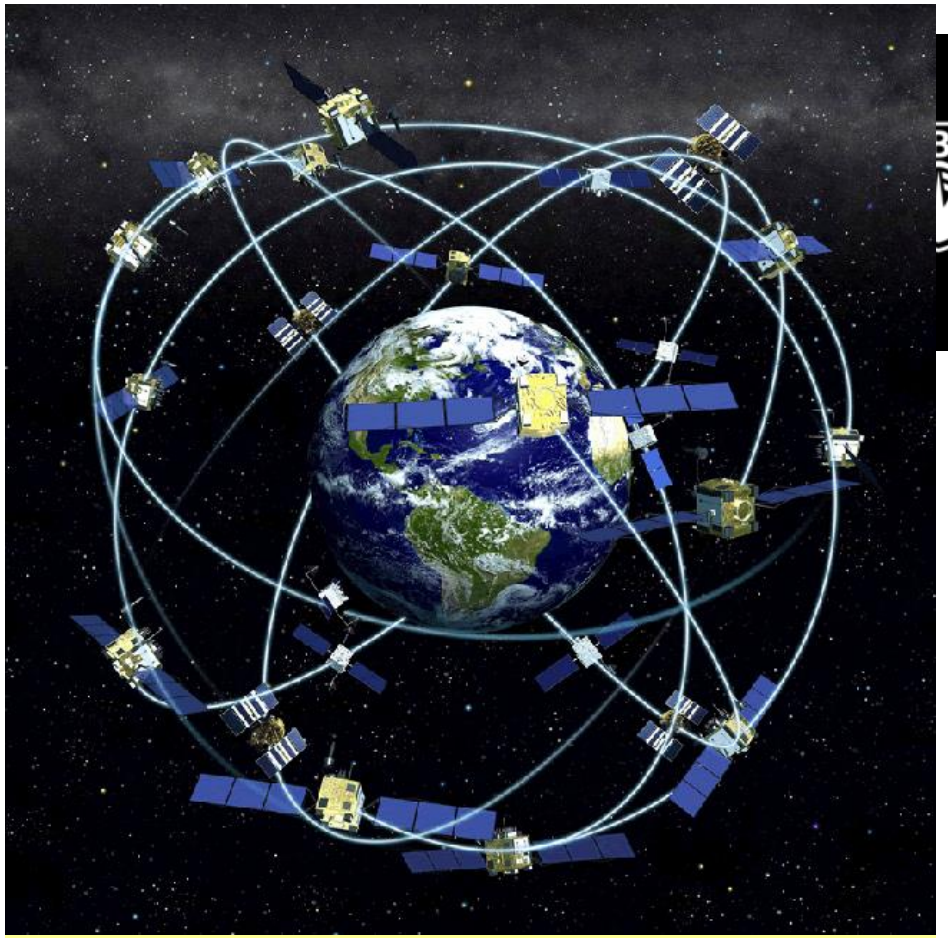
Marine chronometer
@ Wikimedia Commons

Using a Marine Chronometer



Space – New navigation frontier

- Navigators have looked to the sky for direction for thousands of years
- Since 1957, celestial navigation has simply switched from natural objects to artificial satellites
- Navigation satellites are like orbiting landmarks
- If the satellite orbit is known, location on the earth can be determined with at least 4 satellites



Navigation satellites constellation
@ Wikimedia Commons

Practice Questions

- What is the difference between relative and absolute position?
- What is the difference of longitude represented by 12 hours difference in local time (using a marine chronometer)?
- Which methods of historical positioning use absolute positioning and which use relative positioning?
- Why is latitude easy to determine with celestial navigation (at least for the Northern Hemisphere)?

Additional material

- Dava Sovel, 1995. Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time. http://www.amazon.ca/Longitude-Genius-Greatest-Scientific-Problem/dp/080271529X
- Fritz E. Uttmark, 1919. Marq Saint-Hilarie method: for finding a ship's position at seahttp://www.amazon.ca/Marc-St-Hilaire-method-position/dp/B003QMMJXA
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- Navigation principles of positioning and guidance. http://www.springer.com/us/book/9783211008287
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- James A Van Allen. Basic principles of celestial navigation. http://libvolume6.xyz/nauticalscience/bsc/semester5/principlesofnavigationpaper3/principlesofnavigation/principlesofnavigationnotes1.pdf
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