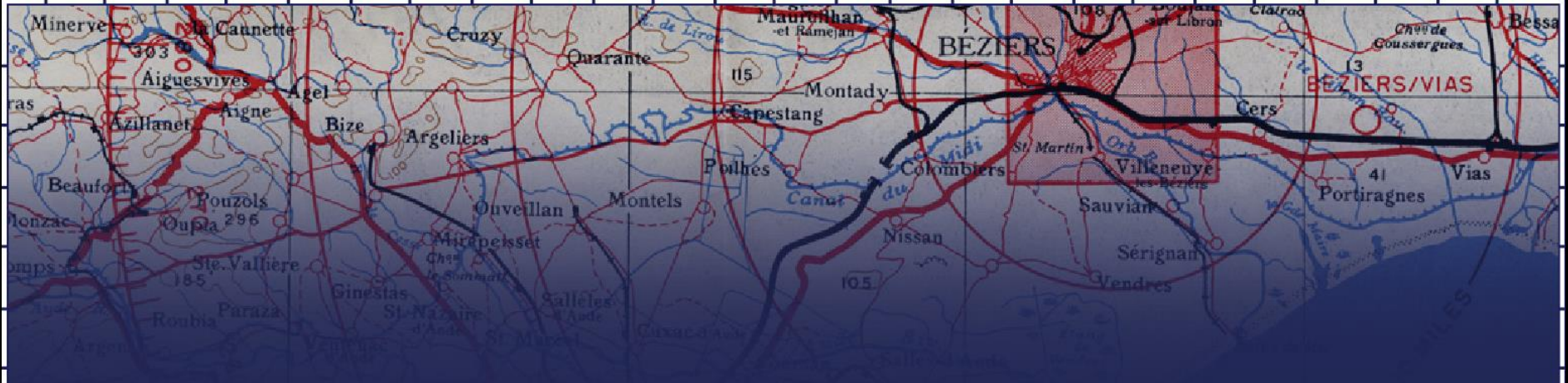


TIME and NAVIGATION

The Untold Story of Getting From Here to There

Andrew Johnston Smithsonian National Air and Space Museum

Time and Navigation:
The untold story of getting from here to there.

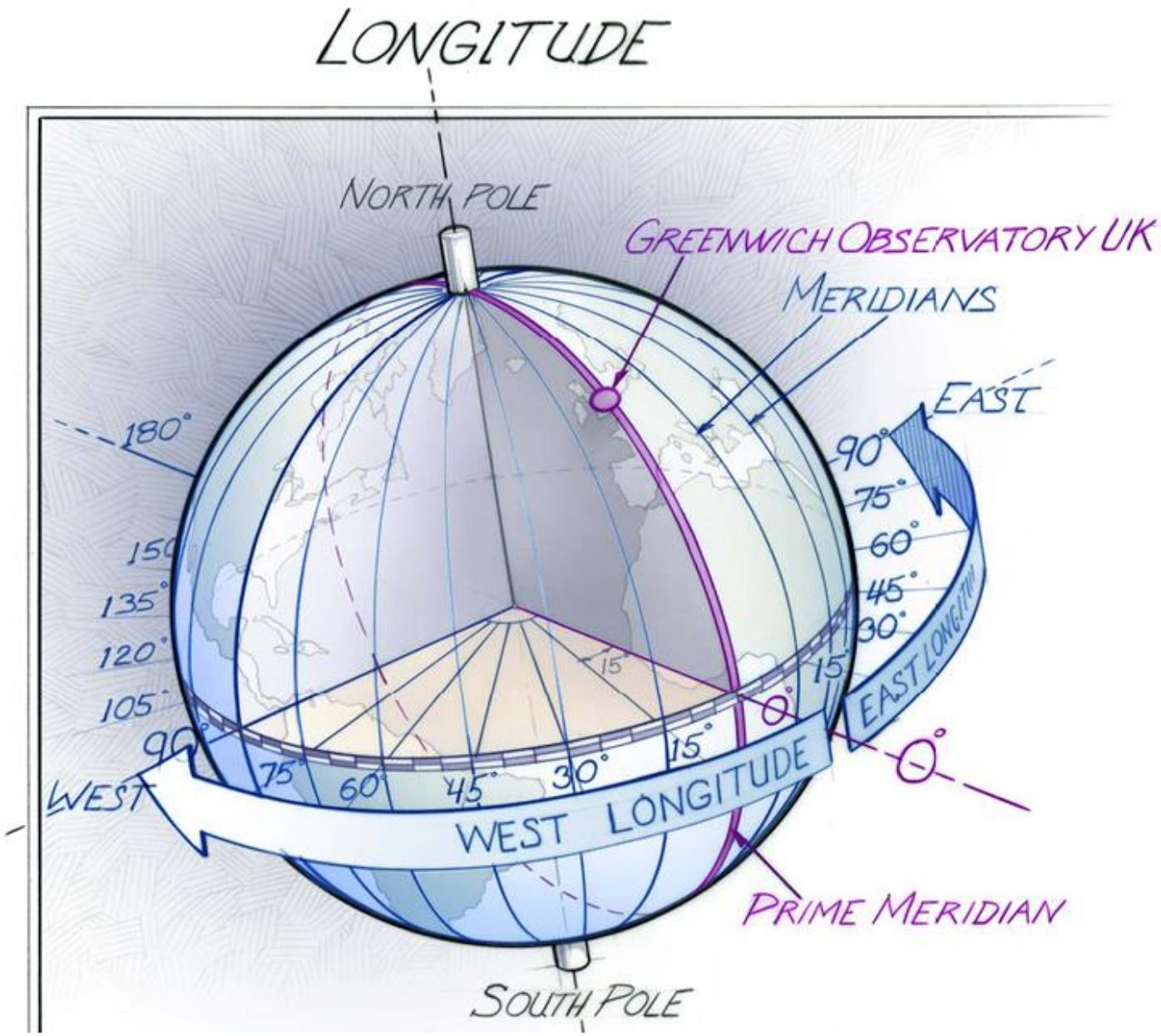
Explores the enduring connection between determining time and position.

"If you want to know where you are,
you need a reliable clock."

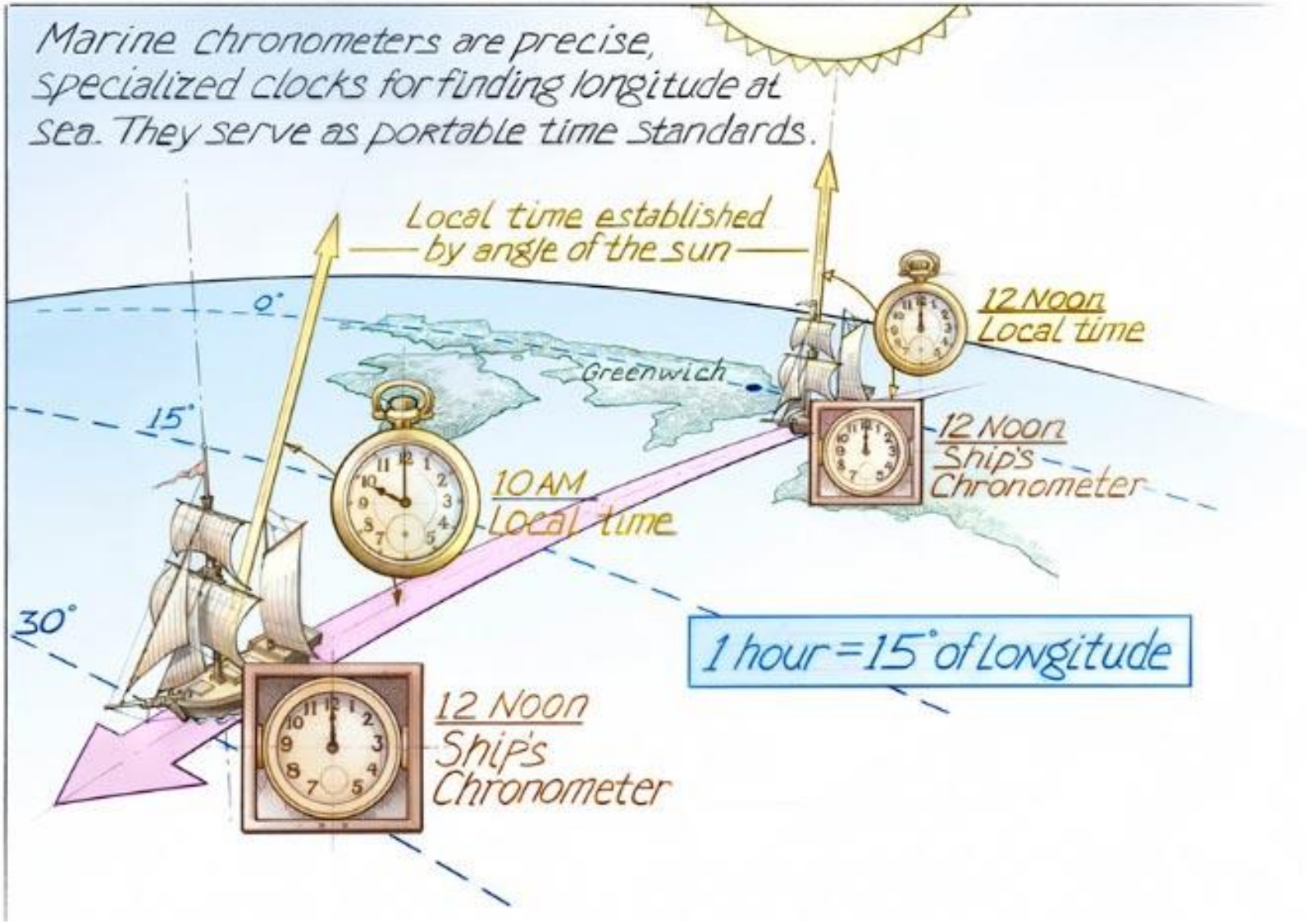
Collaboration of Two Smithsonian Museums:
National Air and Space Museum
National Museum of American History

WELCOME TO
TIME and NAVIGATION

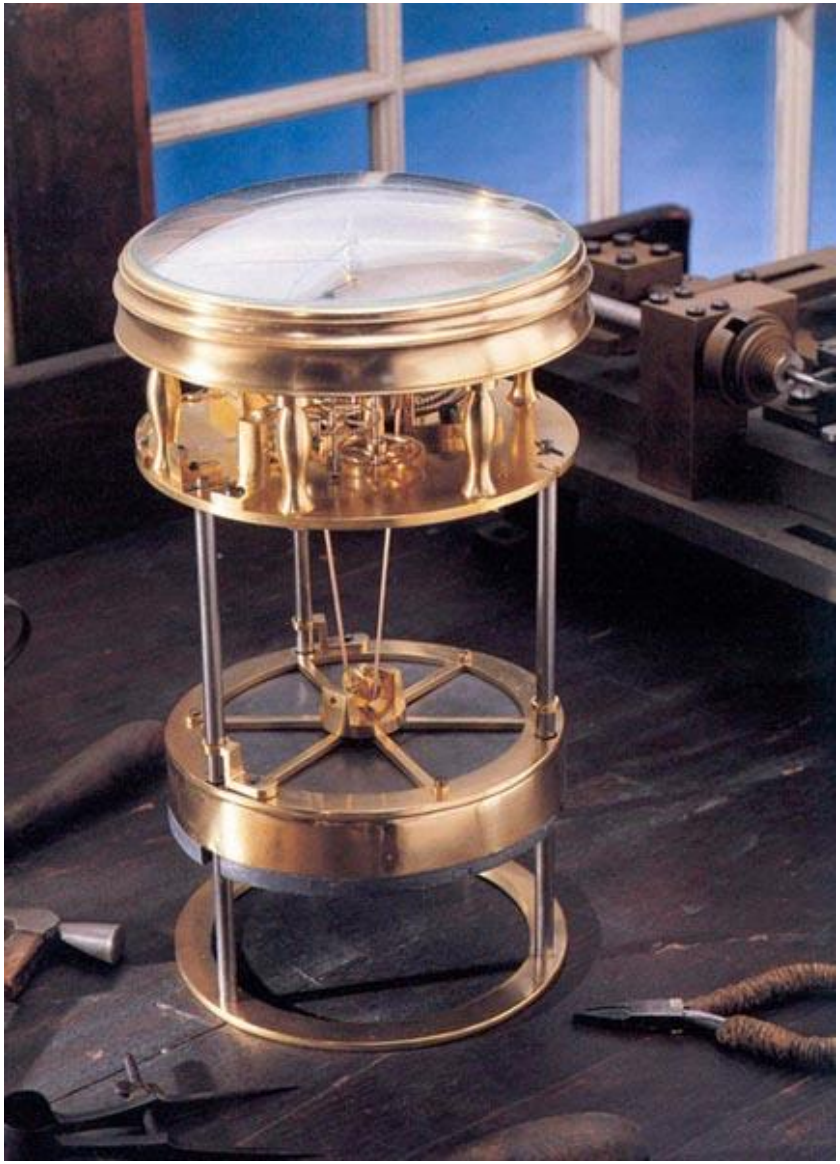
DEAD RECKONING AT SEA


LONGITUDE
NORTH POLE
GREENWICH OBSERVATORY UK
MERIDIANS
EAST
180°
90°
75°
60°
45°
30°
15°
135°
120°
105°
90°
15°
0°
15°
30°
45°
60°
75°
WEST
WEST LONGITUDE
EAST LONGITUDE
0°
PRIME MERIDIAN
SOUTH POLE

Using a Marine Chronometer



Navigation at Sea

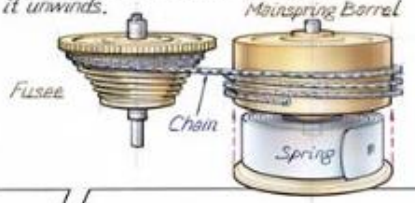


Bond Chronometer (1812)

Chronometer Movement,
John Roger Arnold
(about 1825)

MAINSPRING ARRANGEMENT

Combines the spring with a fusee to equalize the force of the spring as it unwinds.

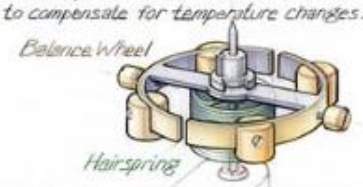


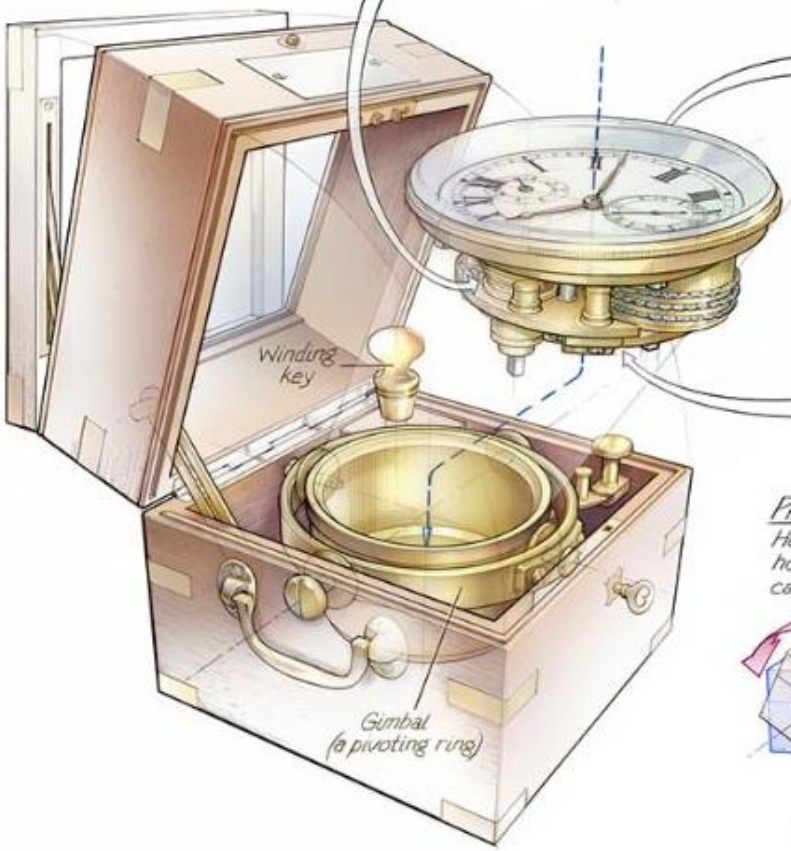
SPRING DETENT ESCAPEMENT

Transfers power from the spring to keep the balance swinging regularly, while interfering with it as little as possible.

BALANCE WHEEL

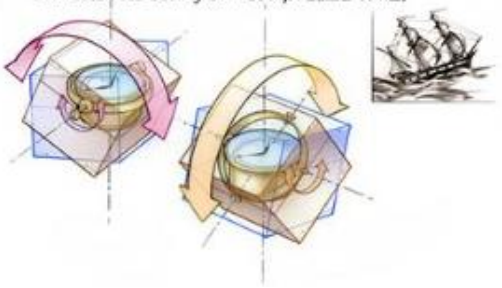
Regulates the pace of the chronometer with a special combination of two metals that expand and contract at different rates to compensate for temperature changes.





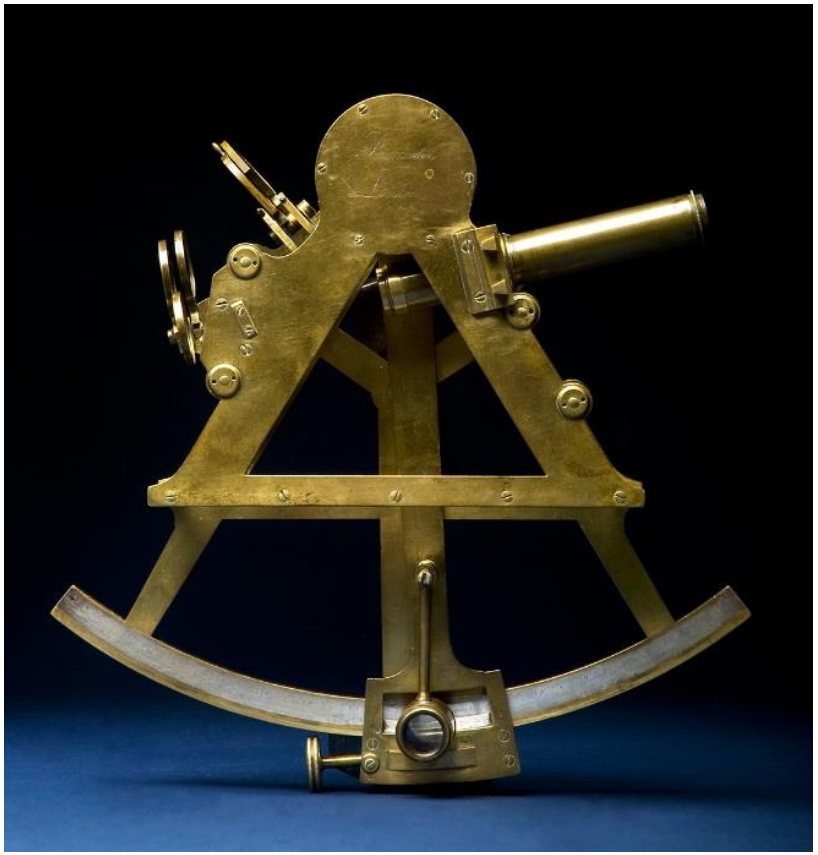
PROTECTIVE BOX WITH GIMBAL

Holds the chronometer level with the horizon to prevent position changes that can alter its ability to keep precise time.



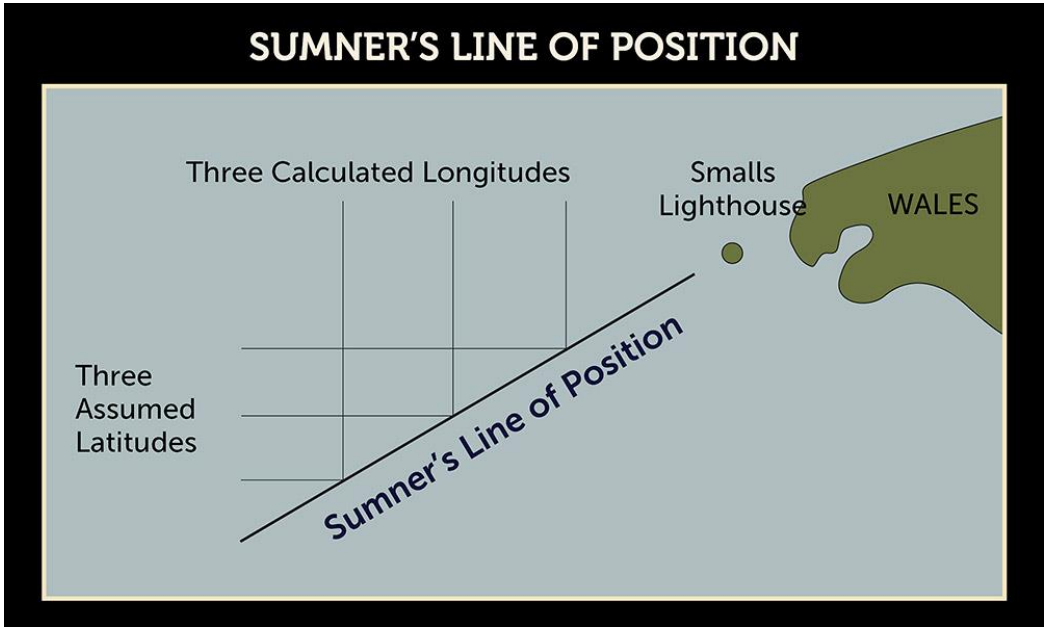
Navigation at Sea

Ramsden Dividing Engine (1775)



Sextant, Jesse Ramsden
(after 1775)

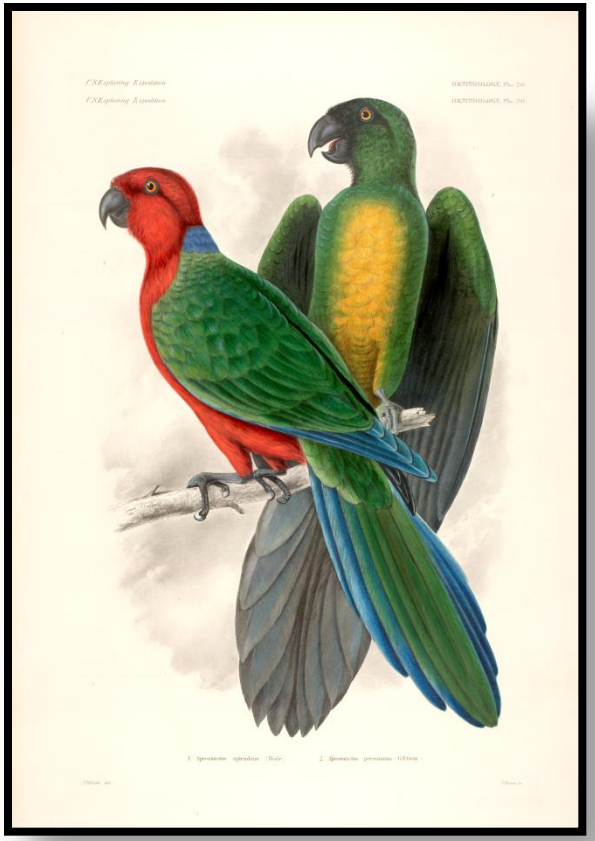
Navigation at Sea

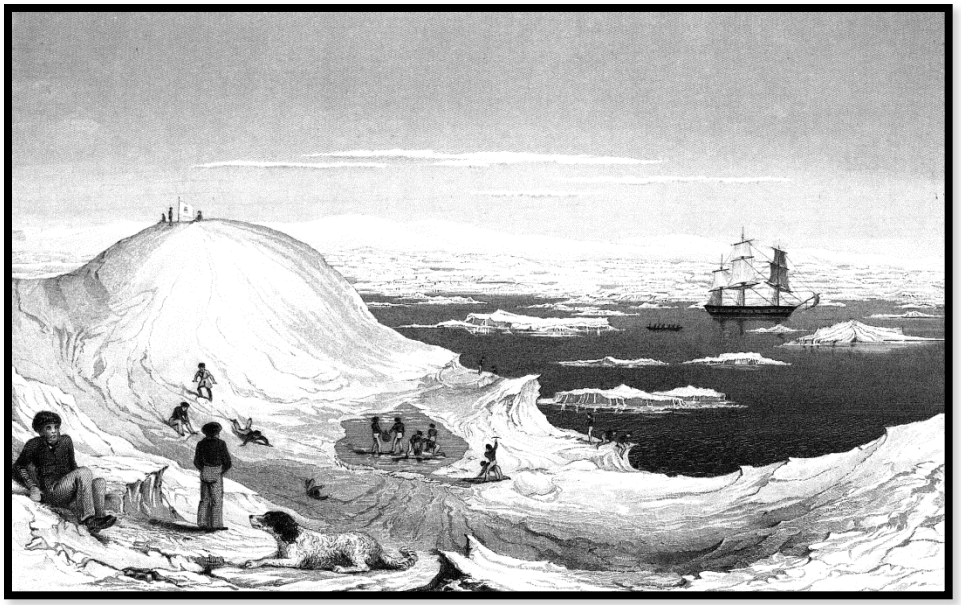


Thomas Sumner's line of constant altitude (voyage 1838, published 1843)

Navigation at Sea

United States Exploring Expedition
(Pacific Ocean 1838-1842)





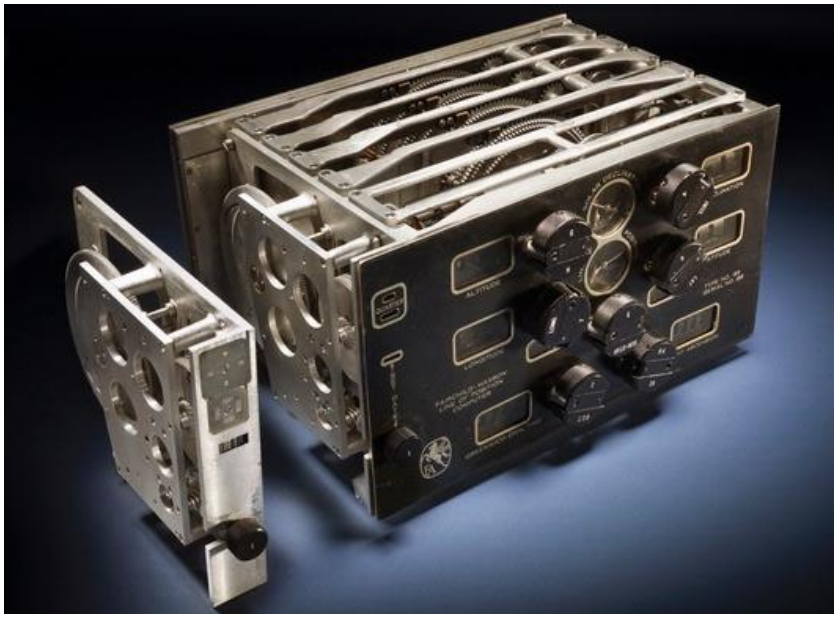
Flying Cloud
(New York – San Francisco 1854)

Navigation in the Air

NC-4 by Ted Wilbur
(Atlantic crossing 1919)

Lockheed Vega *Winnie Mae*
(around the world in 1931, 1933)

Navigation in the Air

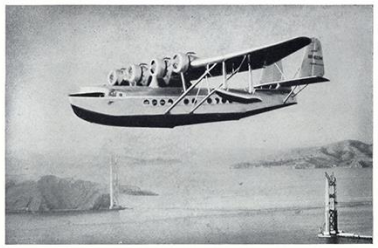


Fairchild-Maxson
Line of Position Computer (1938)

Richie Compass from *Winnie Mae*
(recovered 1935 after Post & Rogers crash)

Navigation in the Air

LONGINES ..the world's most Honored Watch!



The Pan-American Airways used Longines Aviation Watches exclusively in establishing their Trans-Pacific and Trans-Atlantic routes.

5. Honored by...

COL. CHARLES A. LINDBERGH
INVENTOR OF THE LONGINES-LINDBERGH HOUR ANGLE WATCH!
(Manufactured by Longines exclusively. U. S. Pat.)

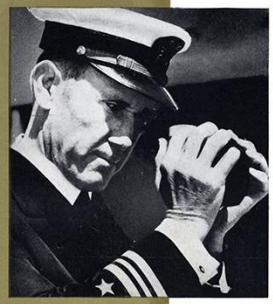
Col. Lindbergh's flight by compass from New York to Paris convinced him of the necessity and importance of air navigation. While studying the subject in 1927 with Lt. Comm. P. V. H. Weems he invented the now famous Lindbergh Hour-Angle Watch. He sought the cooperation of Longines in developing and patenting this watch and appointed Longines to manufacture it exclusively.

LONGINES IS GOVERNMENT STANDARD FOR AIR AND SEA NAVIGATION

Longines is the official timepiece of the National Aeronautical Association. Since 1923 Longines has been the official watch of the International Federation of Aviation for timing world's records. It timed the end of Lindbergh's flight to LeBourget Field. No other make of watch has qualified under the rigid requirements specified for this purpose. A flying record becomes an official record when timed with the official watch . . . the Longines.

6. Honored by...

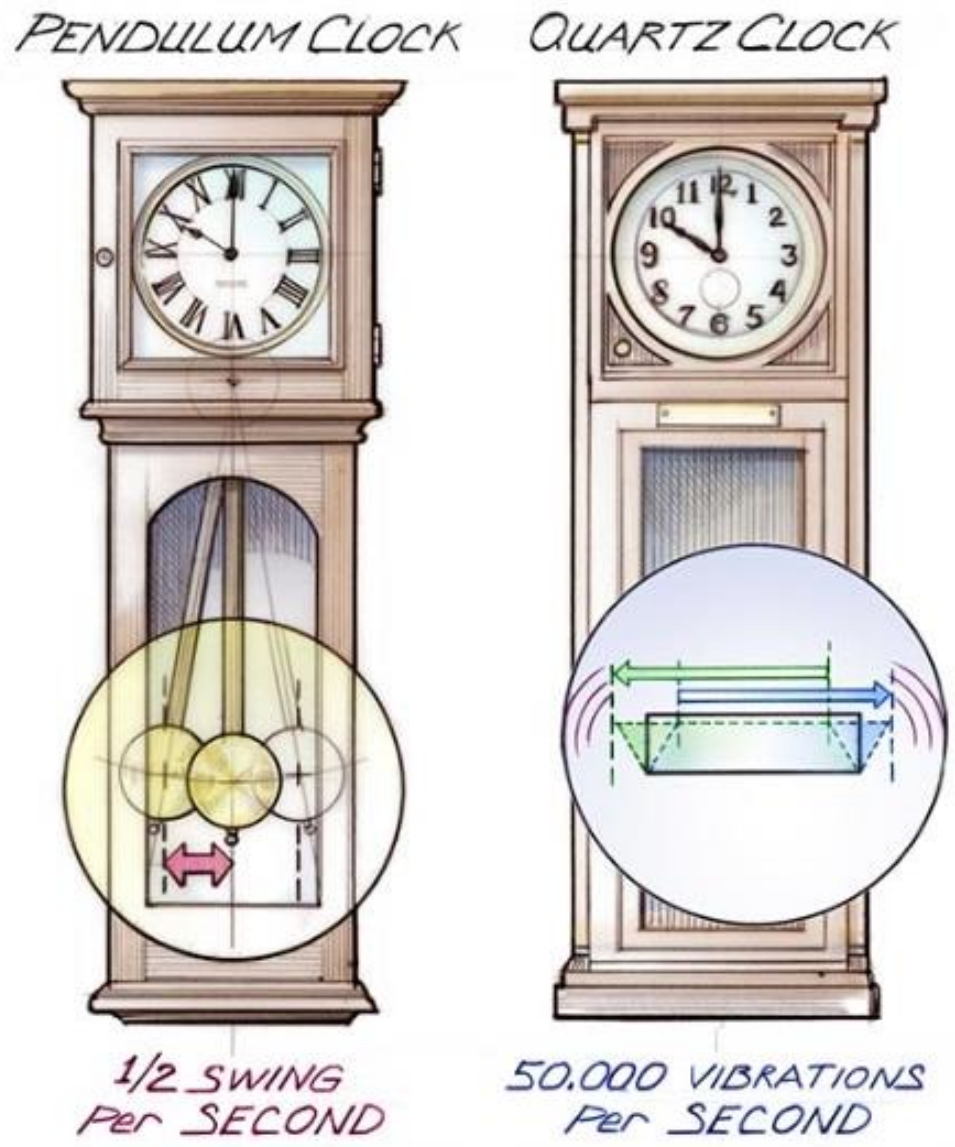
LT. COMM. P. V. H. WEEMS
(INSTRUCTOR OF LINDBERGH)
WHO GAVE LONGINES
HIS SECOND-SETTING WATCH



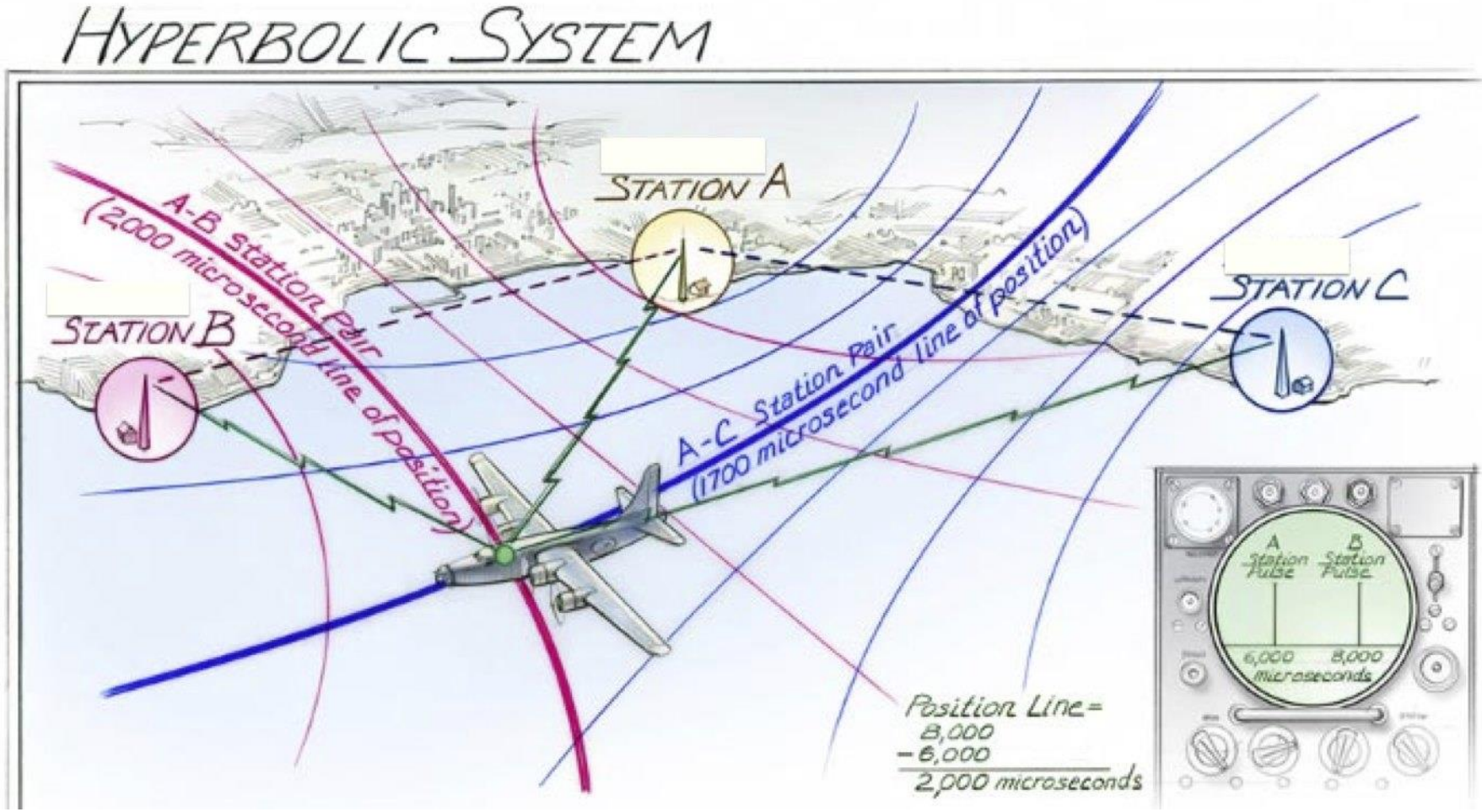
LT. COMM. P. V. H. WEEMS
World's Navigation-Avigation Authority
Instructor of Colonel Charles A. Lindbergh

In his sixteen years as a navigation specialist, Commander Weems has taught thousands of pilots. He was formerly Research Officer in Air Navigation for the U. S. Navy Department—and was honored by the medal of the Aero Club de France for his world-wide services to Aviation. He is an international authority on all forms of navigation by air or sea—and has to his credit a long list of contributions to the new science of "Avigation."

Lt. Comm. P. V. H. Weems, Rtd., has just been appointed chief of the Navigation and Avigation Division of Longines-Wittnauer Co., Inc.


PENDULUM CLOCK
QUARTZ CLOCK
1/2 SWING
Per SECOND
50.000 VIBRATIONS
Per SECOND

Navigation in the Air

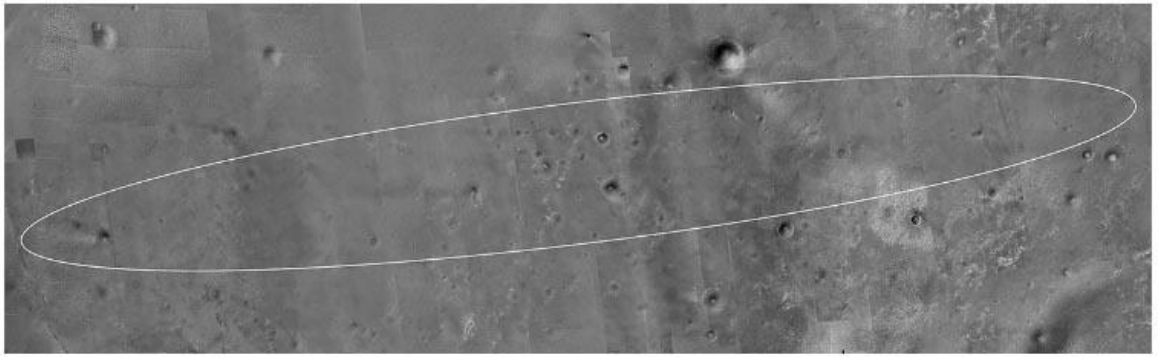


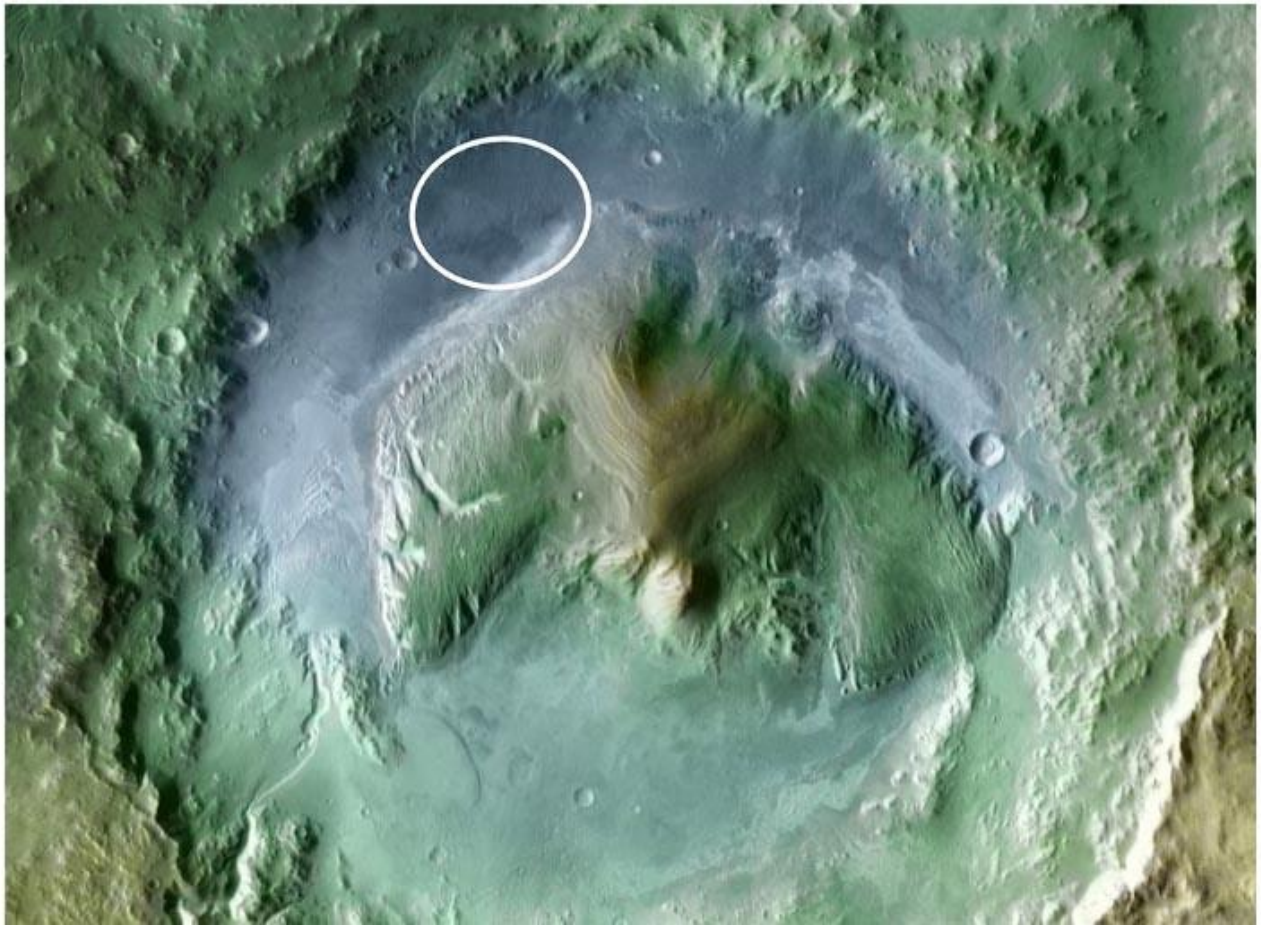
Navigation in Space

70 m antenna at Goldstone

Mariner 10 (1973)

MER Landing Ellipse (2004)



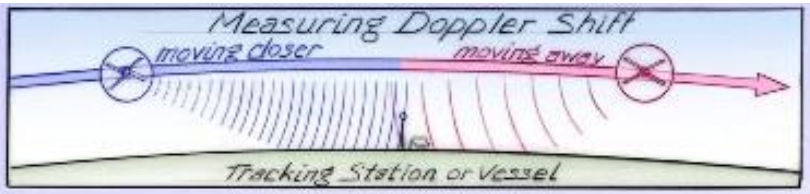


MSL Landing Ellipse (2012)

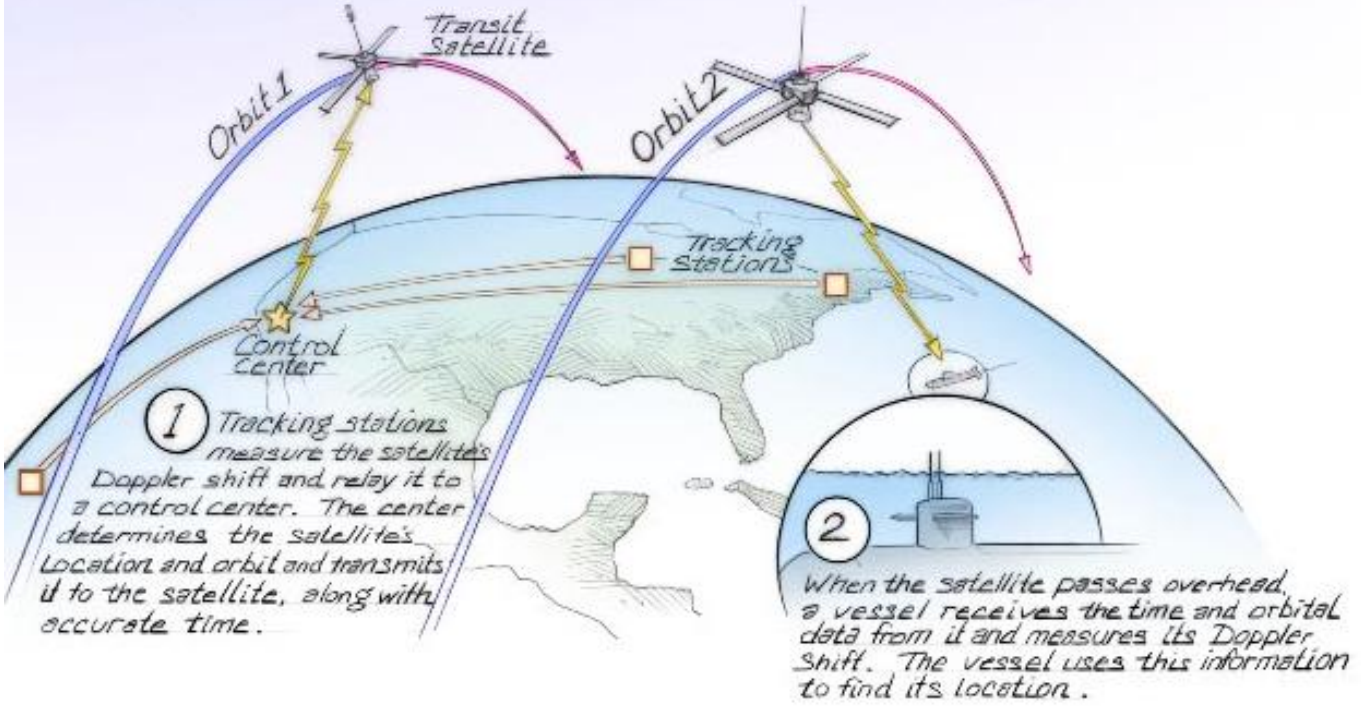
Satellite Navigation

Second Transit satellite (1960)

Transit 5A satellite (1970s)



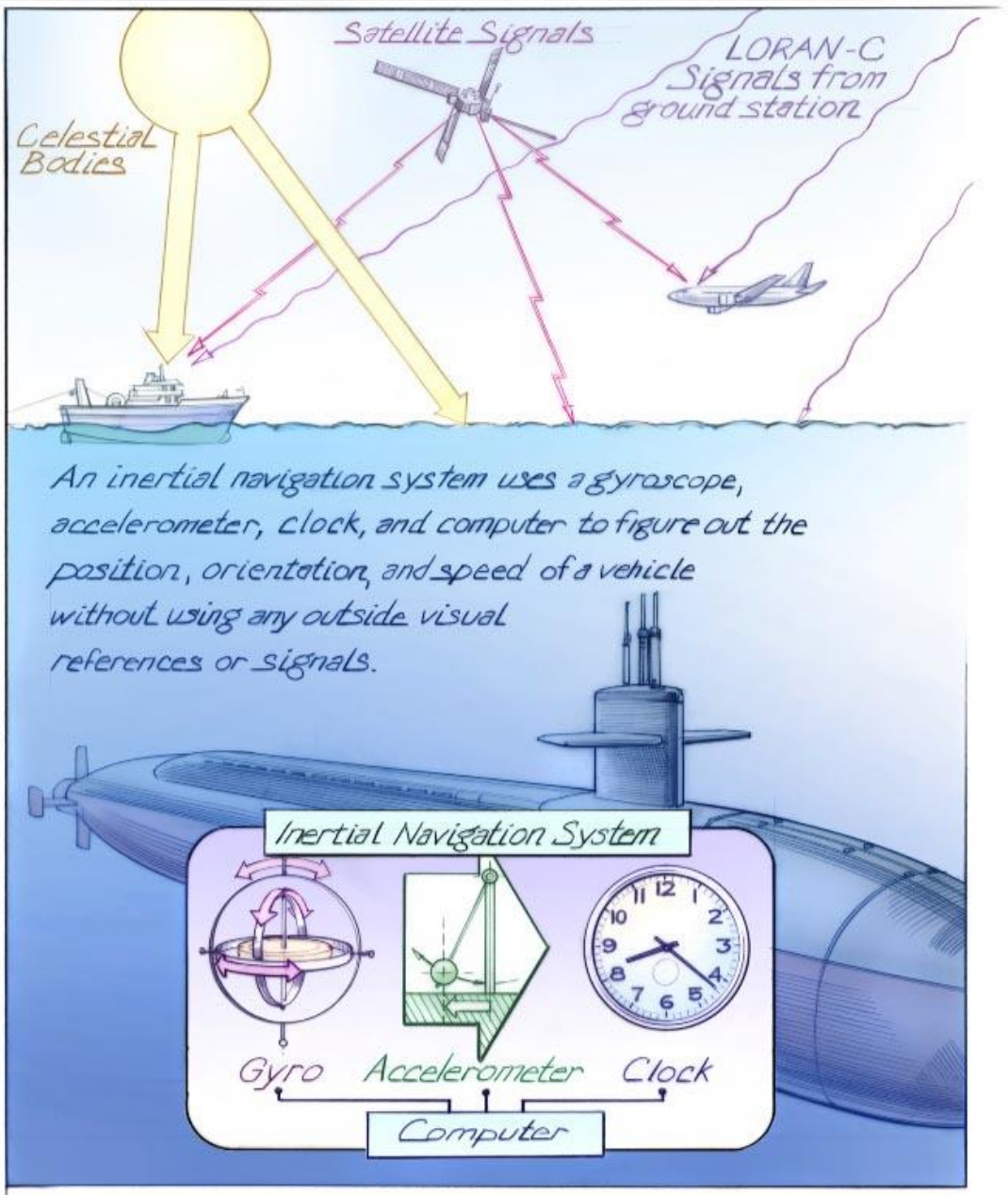
The Doppler shift of signals from a moving satellite is used to determine the satellite's orbit compared to the location of the tracking station. By then inverting the process, a vessel can locate itself compared to the satellite's known location.



Satellite Navigation

SINS from USS Alabama

INERTIAL NAVIGATION



Satellite Navigation

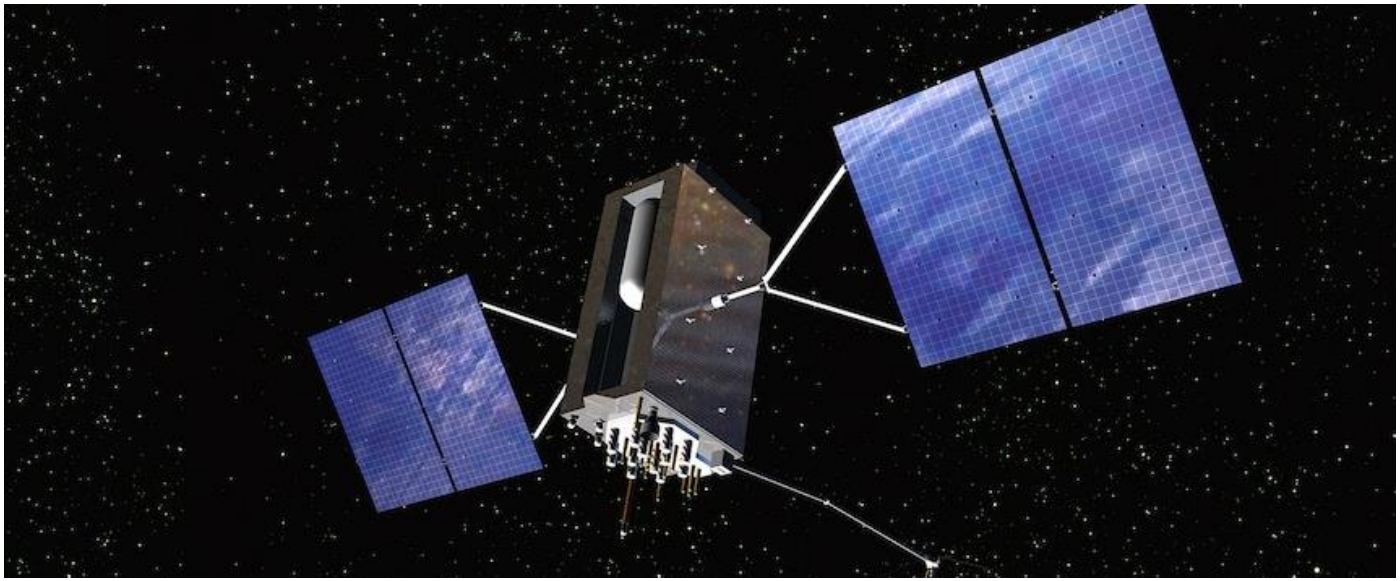
NTS-2 satellite (1977)

Satellite Navigation

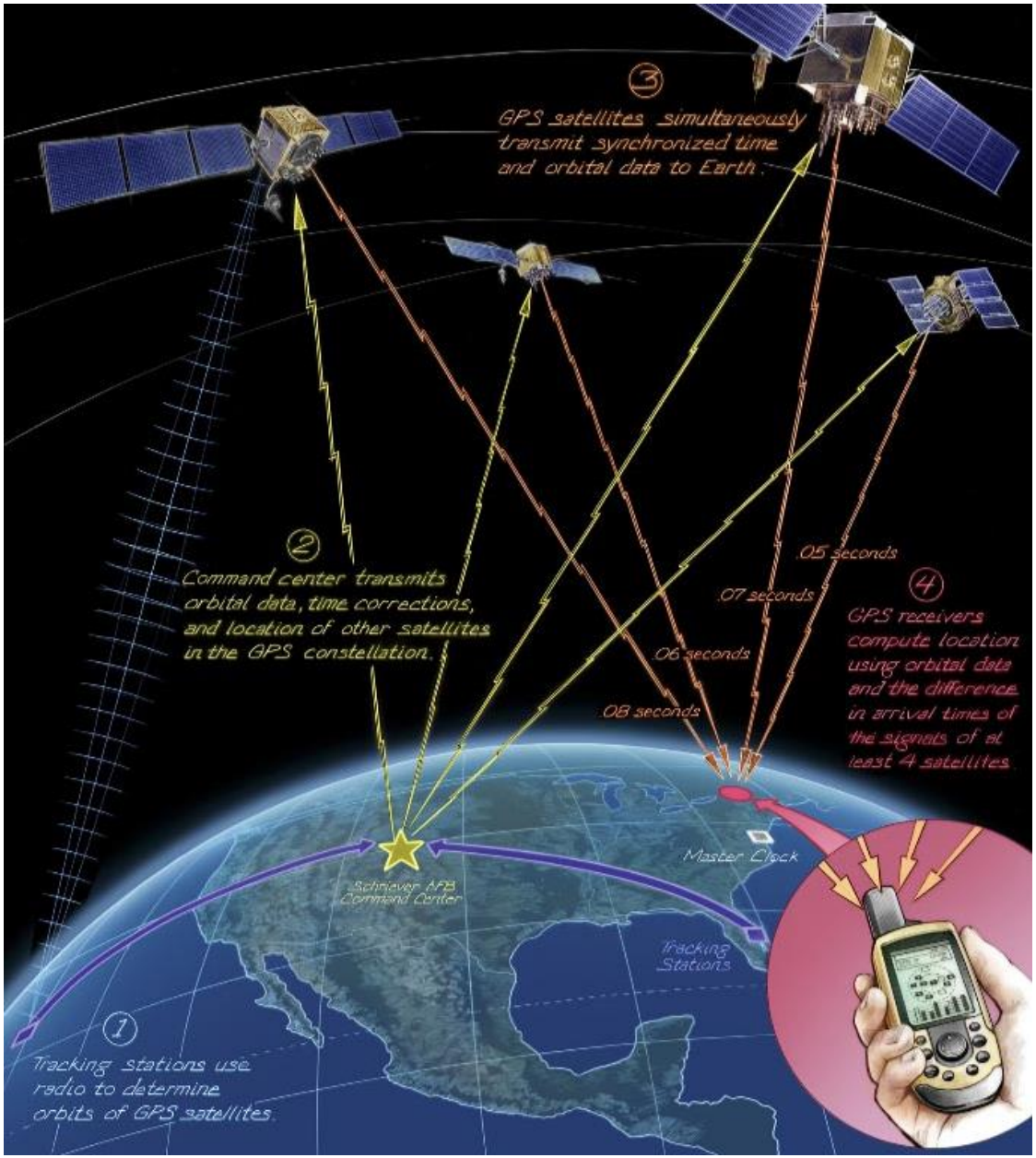
Small Diameter Bomb

T-Hawk

Navigation for Everyone



Navigation for Everyone



NIST-7

Navigation for Everyone

Stanley (2005)

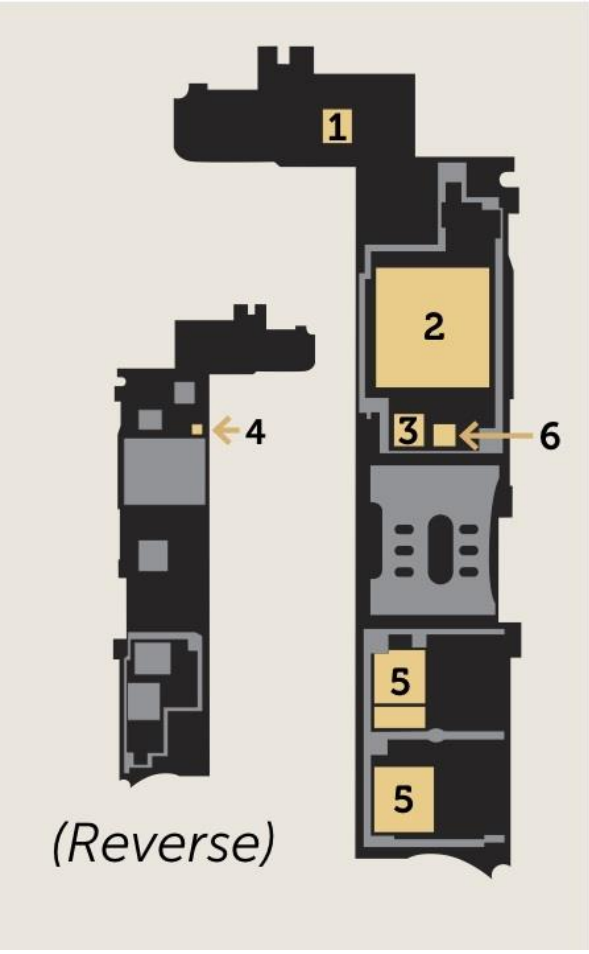
Navigation for Everyone

John Sullivan Roy Bardole Eva González

Navigation for Everyone

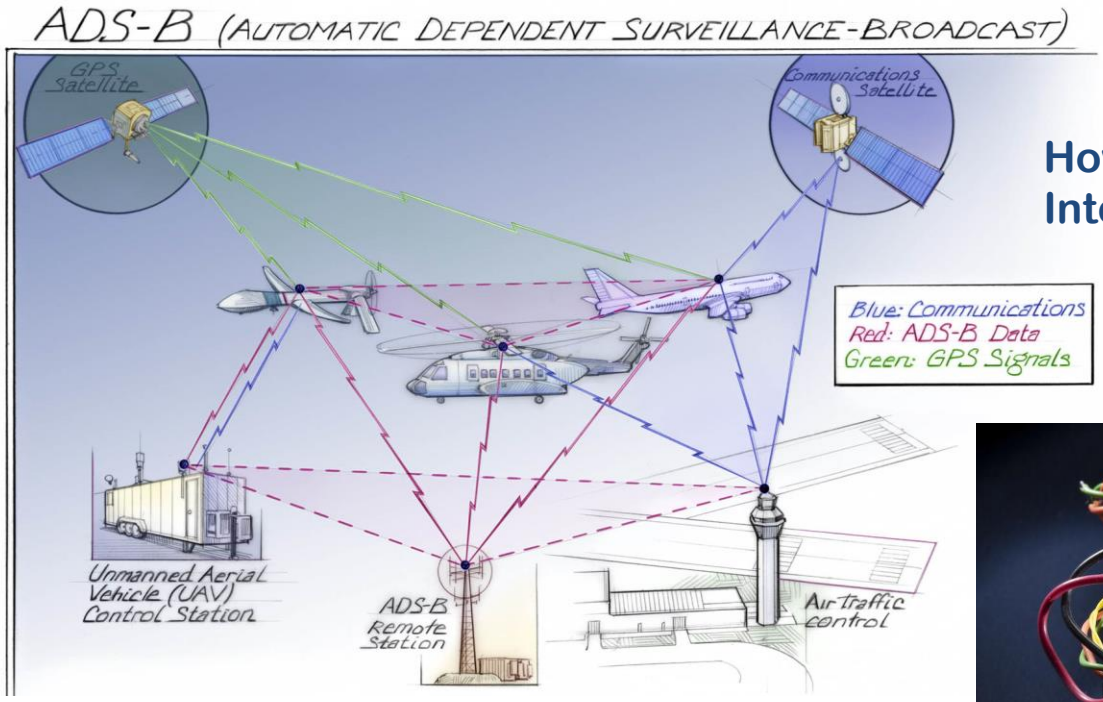
Seiko Epson Digital Assistant (1997)

1 GPS receiver
2 Processor (computer)
3 Three-axis gyroscope
4 Magnetic compass
5 Radio receivers
6 Three-axis accelerometer

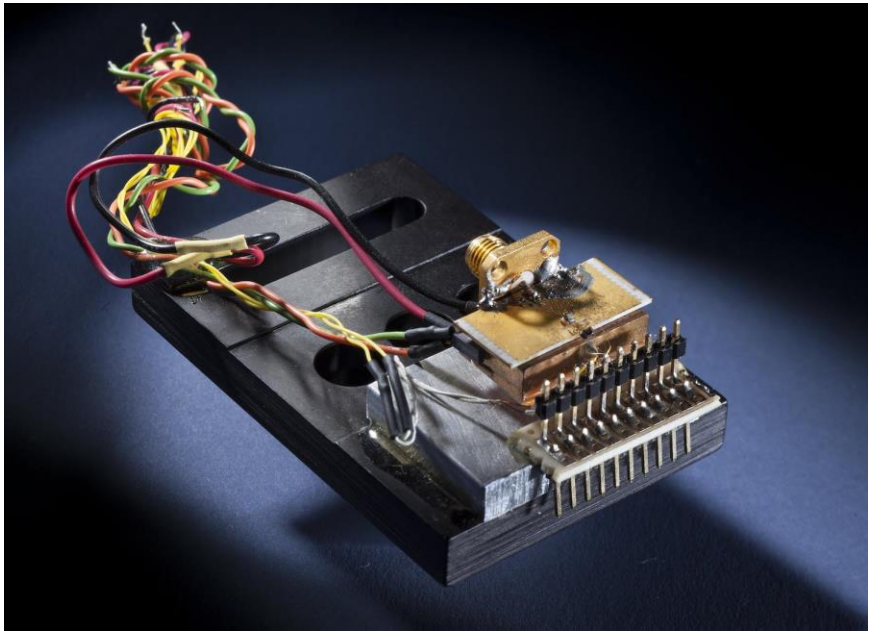


Mobile Components (2012)

Looking Ahead



How can navigation be more robust?
International systems, multiple sources



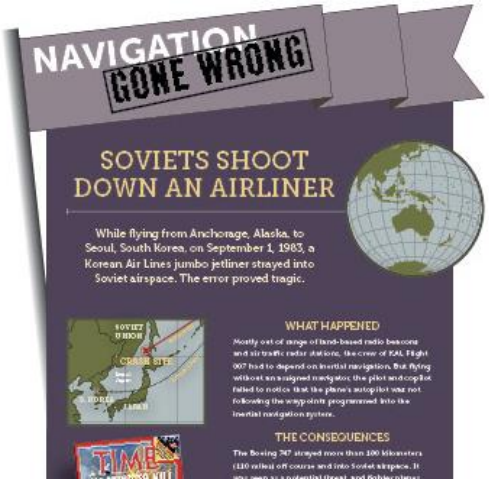
Chip-Scale atomic clock

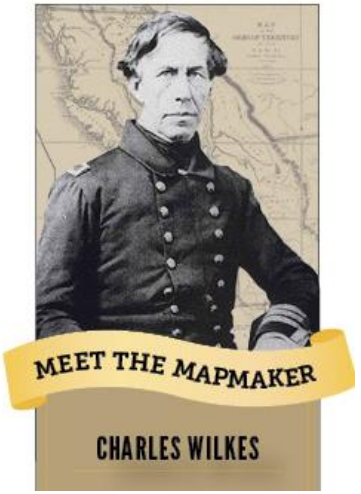
Behinds the Scenes at *Time and Navigation*

Navigation portrait gallery.

16 September 2013:
30th anniversary of presidential statement on civil GPS availability.

KAL 007, ICAO commitment





Behinds the Scenes at *Time and Navigation*

DSN Frequency Standard

Working atomic clock

TIME *and* NAVIGATION

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NORTHROP GRUMMAN CORPORATION

EXELIS INC.

HONEYWELL

NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY

U.S. DEPARTMENT OF TRANSPORTATION

MAGELLAN GPS

NATIONAL COORDINATION OFFICE FOR
SPACE-BASED POSITIONING, NAVIGATION & TIMING

ROCKWELL COLLINS

INSTITUTE OF NAVIGATION

Time and Navigation *open to the public at the National Air and Space Museum*

Please visit web site:

timeandnavigation.si.edu