Nathaniel Bowditch – American Practical Navigator

JOE ALFRED

MARY WASHINGTON ELDERSTUDY

TUESDAY, 15 SEPTEMBER 2020

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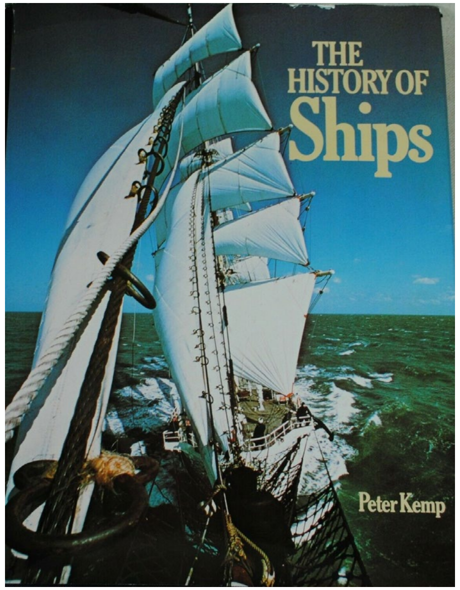
Early Ships

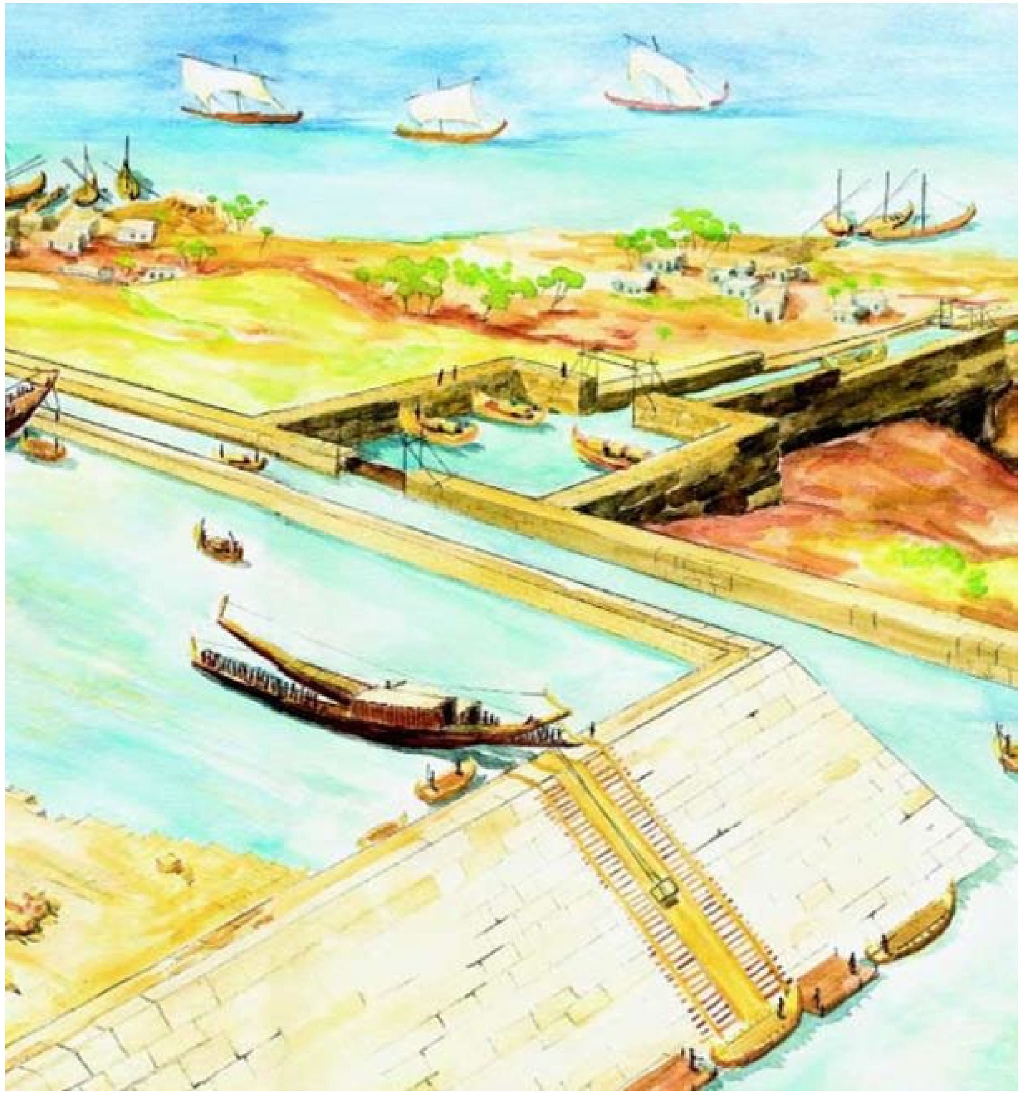
Egyptian, 3800 BC

Khufu's funeral boat, 2566 BC

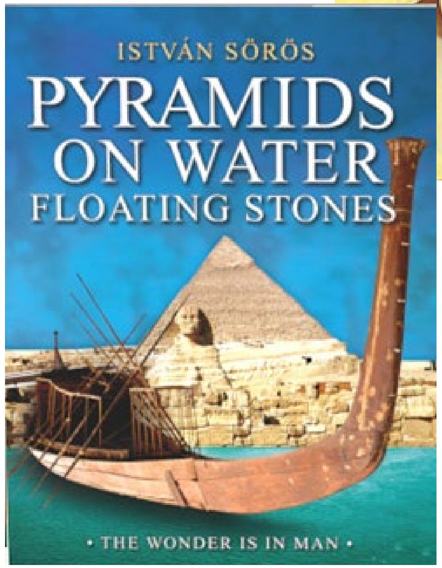


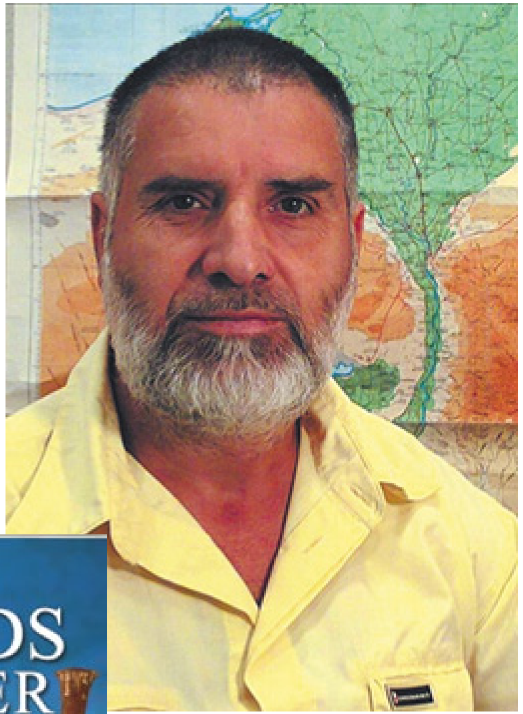
Peter Kemp, *The History of Ships*, Galahad Books, 1978

Early Ships



Egyptian ships used to carry stones and build the pyramids





István Sörös

István Sörös, *Pyramids on Water – Floating Stones*

Early Ships

The trireme derives its name from its **three rows of oars**. As a ship it was fast and agile, and it was the dominant warship in during the 7th to 4th centuries BC, after which it was largely superseded by the larger quadriremes and quinqueremes. **Triremes played a vital role in the Persian Wars**, the creation of the Athenian maritime empire and its downfall in the **Peloponnesian War.**

During the **First Punic War,** the Roman navy was massively expanded and played a vital role in the **Roman victory over Carthage**.

By the 2nd century BC, Rome had subdued the Hellenistic kingdoms of the eastern Mediterranean and achieved complete mastery of the inland sea, **which they called Mare Nostrum**.

Roman quadrireme

John S. Morrison, R.T. Williams, *Greek Oared Ships: 900–322 BC*. Cambridge University Press, 1968

The Defeat of the Spanish Armada
July – August 1588

English ships sailed from Plymouth to attack the Armada and were faster and more manoeuvrable than the larger Spanish galleons, enabling them to fire on the Armada without loss as it sailed east off the south coast of England.

The Armada could have anchored in the Solent between the Isle of Wight and the English mainland and occupied the Isle of Wight, but Medina Sidonia was under orders from King Philip II to meet up with the Duke of Parma's forces in the Netherlands so England could be invaded by Parma's soldiers and other soldiers carried in ships of the Armada.

English guns damaged the Armada and a Spanish ship was captured by Sir Francis Drake in the English Channel.

The Defeat of the Spanish Armada
July – August 1588

Duke of Medina Sidonia

San Martin – flagship of the Spanish Armada

The **Spanish Armada, Spanish: *Grande y Felicísima Armada*, literally 'Great and Most Fortunate Navy**' was a Hapsburg Spanish fleet of 130 ships that sailed from Corunna in late May 1588, under the command of the Duke of Medina Sidonia, with the purpose of escorting an army from Flanders to invade England.

Medina Sidonia was an aristocrat without naval command experience but was made commander by King Philip II. The aim was to overthrow Queen Elizabeth I and her establishment of Protestantism, to stop English interference in the Spanish Netherlands and to stop the harm caused by English and Dutch privateering ships that interfered with Spanish interests in the Americas.

John Knox Laughton, *State Papers Relating to the Defeat of the Spanish Armada,* English Navy Records Society, 1588

The Defeat of the Spanish Armada
July – August 1588

English fireships launched at the Spanish Armada

	England & Dutch Republic	Spain & Parma
Ships of the line	34	22
Armed merchantmen	163	108
Flyboats	30	
Fireships	8	
Killed in battle	50-100	11,000
Wounded	400	800
Died from disease, drowning, starvation or slaughter	6,000 - 8,000	5,000
Captured		397
Ships destroyed	8	67

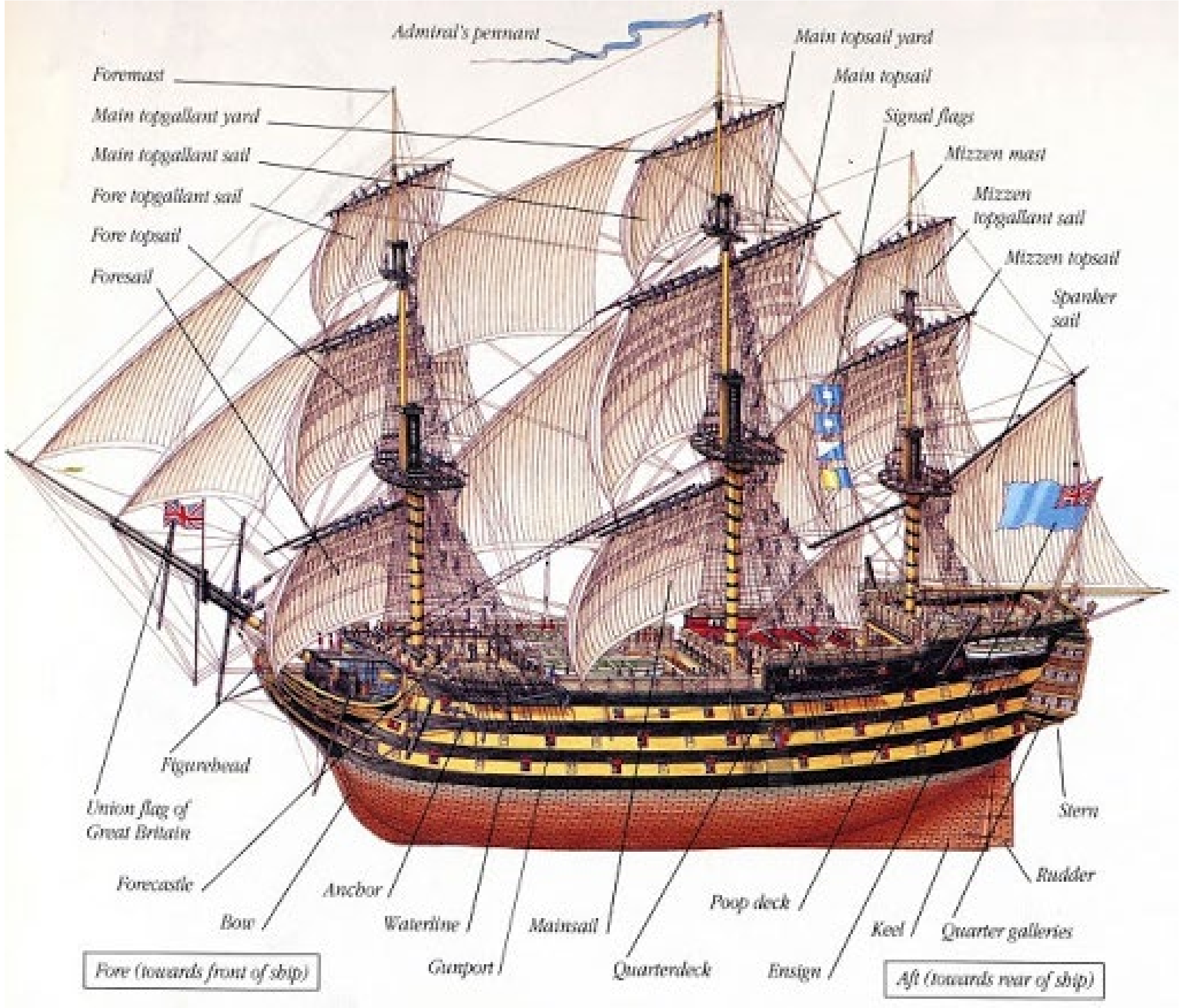
John Knox Laughton, *State Papers Relating to the Defeat of the Spanish Armada,* English Navy Records Society, 1588

Early Ships

On 12 December 2017, the **Portuguese Navy commemorated the 700th anniversary** of its official creation by King Denis of Portugal. The Navy played a key role at the beginning and during the great voyages of the 15th and 16th centuries. The resulting of this **technical and scientific discoveries led Portugal to develop advanced ships, including the caravel**, new and more sophisticated types of ships for inter ocean travel and to find the sea route to the East and routes to South America and Northern North America.

MacTutor using Garcia de Resende, *Vida e feitos d' el-rey Dom João Segundo*, 1545

Early Ships



English Man-of-War 1700s

The man-of-war was developed in Portugal in the early 15th century with the addition of a second mast to form the carrack. The 16th century saw the carrack evolve into the galleon and then the ship of the line.

Sir John Hawkins developed the man-of-war design with three masts, each with three to four sails. The ship could be **up to 60 meters long and could have up to 124 guns;** four at the bow, eight at the stern, and 56 in each broadside. All these cannons required three-gun decks to hold them, one more than any earlier ship. It had a maximum sailing speed of eight or nine knots.

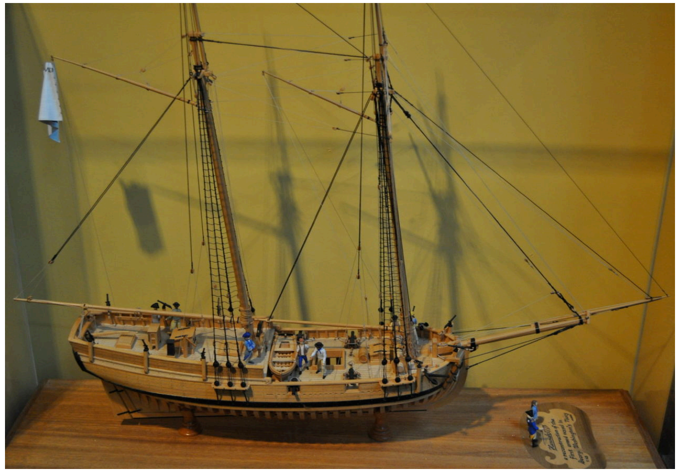
Definition: *man-of war*, Collins English Dictionary

The American Navy

The first formal movement for the creation of a Continental navy came from Rhode Island because its merchants' widespread shipping activities had been severely harassed by British frigates. **On 26 August 1775, the Rhode Island General Assembly passed a resolution that there be a single Continental fleet** funded by the Continental Congress. The resolution was introduced in the Continental Congress on 3 October 1775, but was tabled.

In the meantime, **George Washington had begun to acquire ships**, starting with the **schooner Hannah** which was chartered by Washington from merchant and Continental Army Lieutenant Colonel John Glover of Marblehead, Massachusetts. *Hannah* was commissioned and launched on 5 September 1775, under the command of Captain Nicholson Broughton from the port of Beverly, Massachusetts.

Captain Nicholson Broughton



Schooner Hannah
with four 4-pound guns

Resolution of the Continental Congress that marked the establishment of what is now the United States Navy

Resolved, That **a swift sailing vessel, to carry ten carriage guns, and a proportionable number of swivels, with eighty men,** be fitted, with all possible despatch, for a cruise of three months, and that the commander be instructed to cruize eastward, **for intercepting such transports as may be laden with warlike stores** and other supplies for our enemies, and for such other purposes as the Congress shall direct.

That a Committee of three be appointed to prepare an estimate of the expence, and lay the same before the Congress, and to contract with proper persons to fit out the vessel. *Resolved*, that another vessel be fitted out for the same purposes, and that the said committee report their opinion of a proper vessel, and also an estimate of the expence.

Jack Sweetman, *American Naval History: An Illustrated Chronology of the U.S. Navy and Marine Corps, 1775–present, 2002,* Naval Institute Press

The American Navy

The United States Navy recognizes 13 October 1775 as the date of its official establishment, the passage of the resolution of the Continental Congress at Philadelphia that created the Continental Navy. On this day, Congress authorized the purchase of two vessels to be armed for a cruise against British merchant ships; these ships became Andrea Doria with fourteen 4-pound guns and Cabot with fourteen 6- pound guns.

The first ship in commission was the *USS Alfred* with twenty 9-pound guns and ten 6-pound guns which was purchased on 4 November and commissioned on 3 December by Captain Dudley Saltonstall. On 10 November 1775, the Continental Congress passed a resolution calling for two battalions of Marines to be raised for service with the fleet. John Adams drafted its first governing regulations, which were adopted by Congress on 28 November 1775 and remained in effect throughout the Revolutionary War. The Rhode Island resolution was reconsidered by the Continental Congress and was passed on 13 December 1775, authorizing the building of **thirteen frigates** within the next three months: **five ships of 32 guns, five with 28 guns and three with 24 guns**.

USS Alfred

Jack Sweetman, *American Naval History: An Illustrated Chronology of the U.S. Navy and Marine Corps, 1775–present, 2002,* Naval Institute Press

Major Naval Power Strength During the American Revolution

Type of Ship (# of guns)	American	French	Spanish	Dutch	Allied Total	British
100 - 110		6	2		8	3
98 & 90						13
86 & 84		2	2		4	1
80		7	7		14	3
76				1	1	
74		48	1	4	53	57
70 & 68			48	5	53	2
64		27	11	9	47	34
60			4	5	9	5
56 & 54				12	12	
50 or less	17	10	2	6	35	17
TOTAL	17	100	77	42	236	135

Anthony Preston, David Lyon, John Batchelor, *Navies of the American Revolution*, 1975

Battle of the Chesapeake – 5 September 1781

The American Revolution lasted a decade –

- 22 different navies and thousands of privateers from tens of different nations
- Fought on five different oceans as well as on landlocked lakes and majestic rivers and ankle-deep swamps
- More large-scale fleet battles than any other naval war of the century

Including, the most strategically significant naval battle in all of British, American or French history.

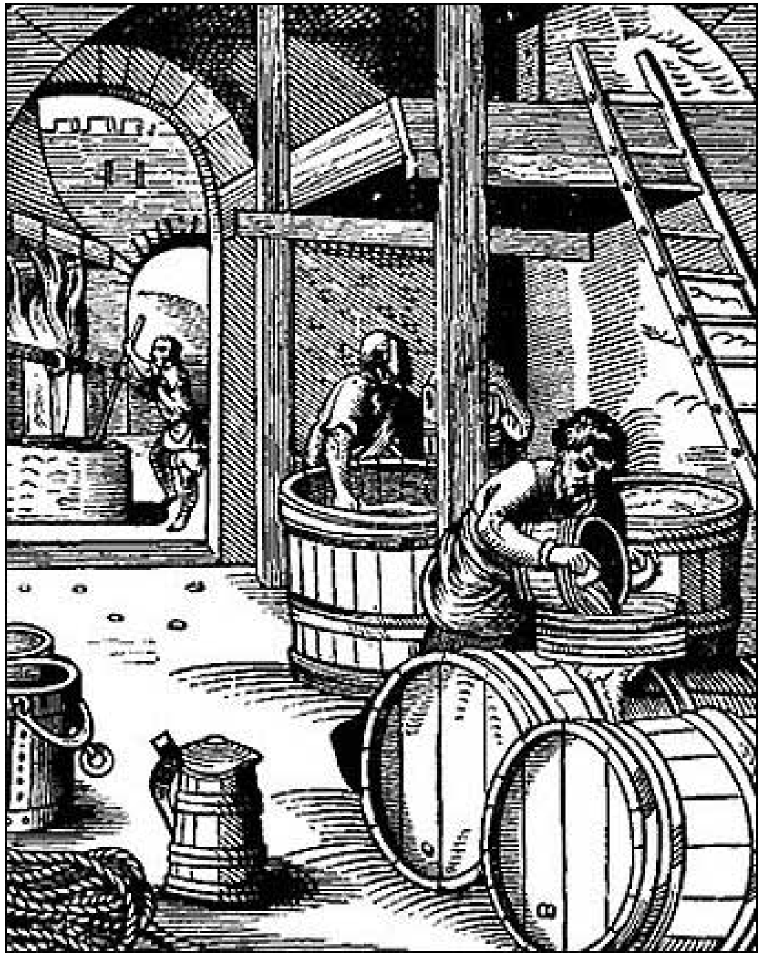
The **Battle of the Chesapeake of 1781, s**ometimes known as the **Battle of the Virginia Capes**

A British fleet intent on rescuing British General Charles Cornwallis, who was stranded at Yorktown, **failed to withstand a French attack and was forced to retreat.** Without naval support, Cornwallis had no choice but to surrender, thus altering the political landscape in Britain, directly leading to the appointment of a government committed to ending the war and granting the rebellious colonies their independence.

US Naval Institute

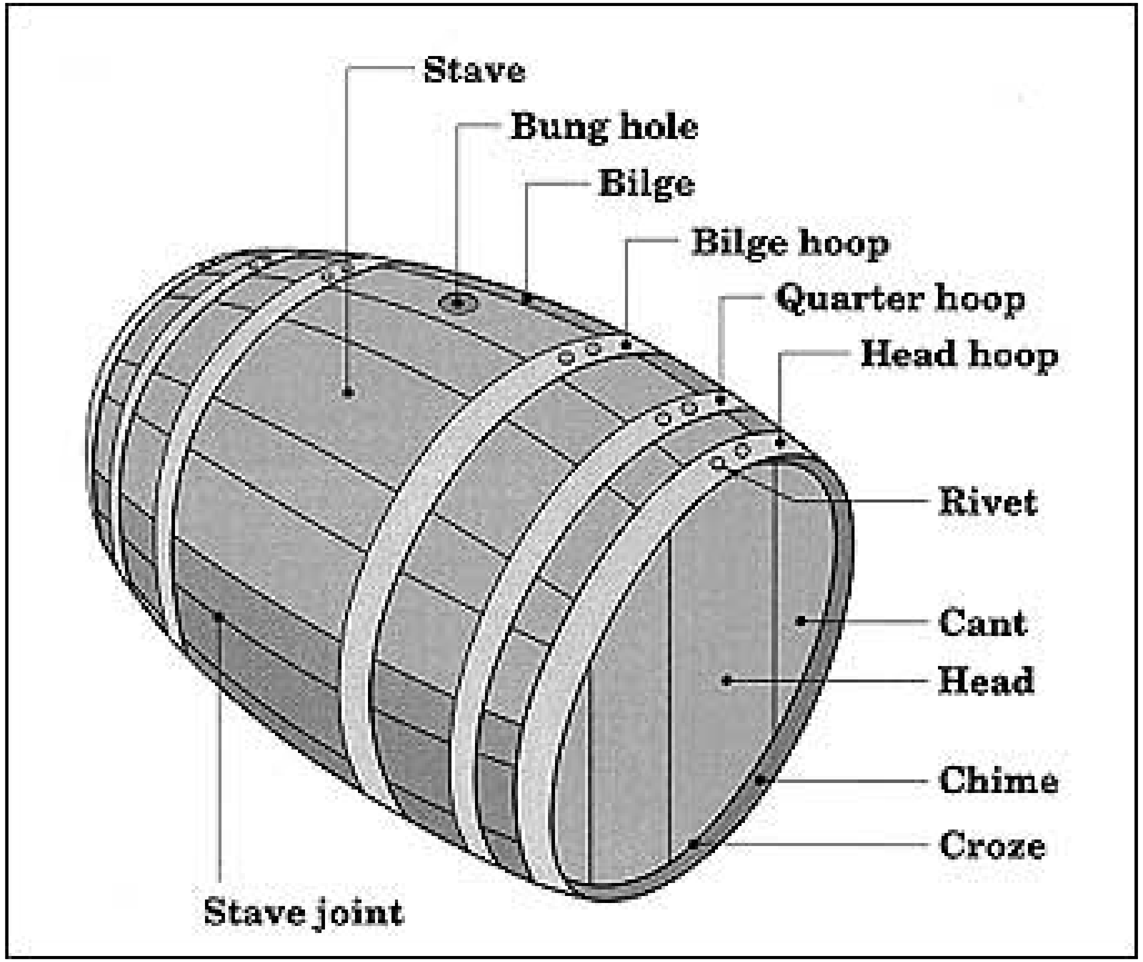
Nathaniel Bowditch was born in Salem, Massachusetts. He was the second of three children born to Habakkuk and Mary Ingersoll Bowditch. He had an older sister Elizabeth and a younger sister Lois. Nathaniel's family moved to Danvers, also in Massachusetts, while he was still a baby. After a few years, when Nathaniel was seven years old, they returned to Salem.

Habakkuk Bowditch was a cooper, that is a maker and repairer of wooden barrels and casks. The colonial trade that makes barrels and various casks is known as a cooper. The work was performed in a cooperage. It is a trade that dates back well over 4000 years. The word "cooper" is derived from "cuparius" of Roman times, makers of cupals or wooden casks in which wine producers of Cisalpine Gaul stored their wares.



Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

Nathaniel Bowditch (1773 – 1838)



Traditional Cask Capacities	
Blood Tub	7.5 gallons
Firkin	9 gallons
Kilderkin	18 gallons
Barrel	36 gallons
Hogshead	54 gallons
Puncheon	72 gallons
Butt	108 gallons
Pipe	108 – 116 gallons

Website: colonialsense.com

Kegs come in many sizes

Size	gallons	pints	12-ounce bottles
half barrel	15.5	124	165
fifty liter	13.2	105	140
quarter barrel	7.75	62	83
one-sixth barrel	5.16	41	55

Website: Beer Run

Nathaniel Bowditch (1773 – 1838)

Chandler Shop

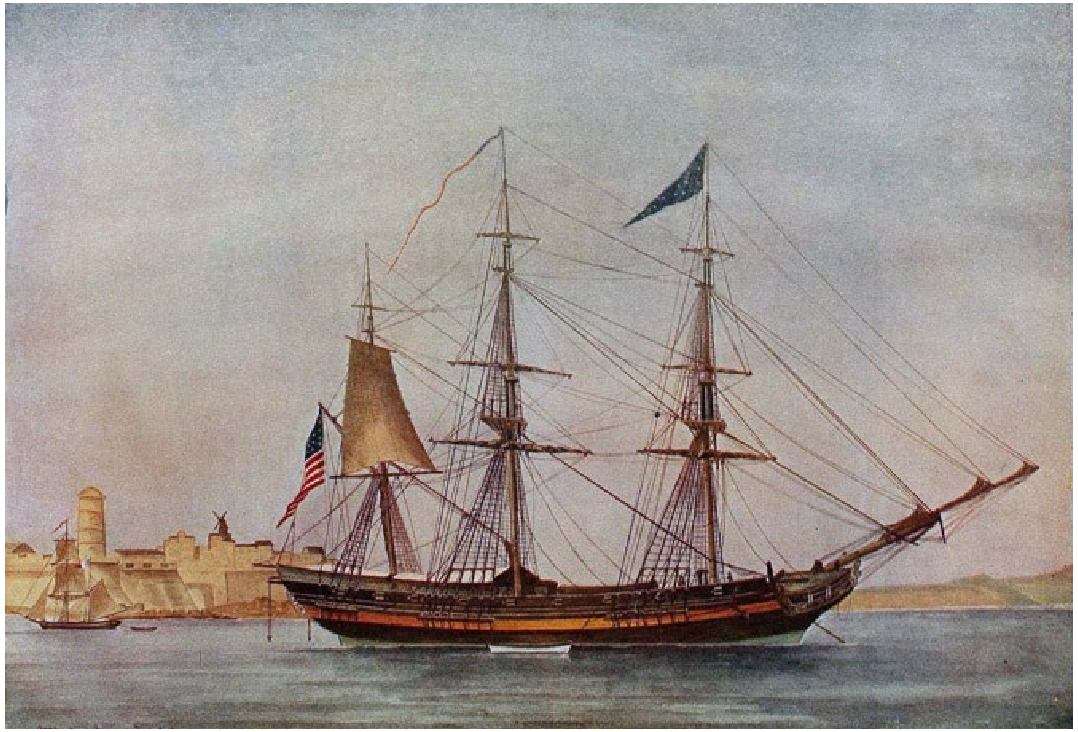
Nathaniel's formal education had to end when he was ten and he began working in his father's cooperage shop. After two years, **his father's business collapsed**, and he became an apprentice clerk in the ship's chandler shop of Hodges and Ropes in Salem in 1785. This shop dealt in provisions and supplies for ships, including those made of tallow or wax, such as candles and soap. In 1790 Bowditch, aged seventeen by this time, changed his employers and began working for the shop of Samuel C. Ward.

Although Bowditch was working as a clerk, he was educating himself throughout this period - **He acquired skill in languages and considerable knowledge of mathematics, astronomy and physics.**

Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

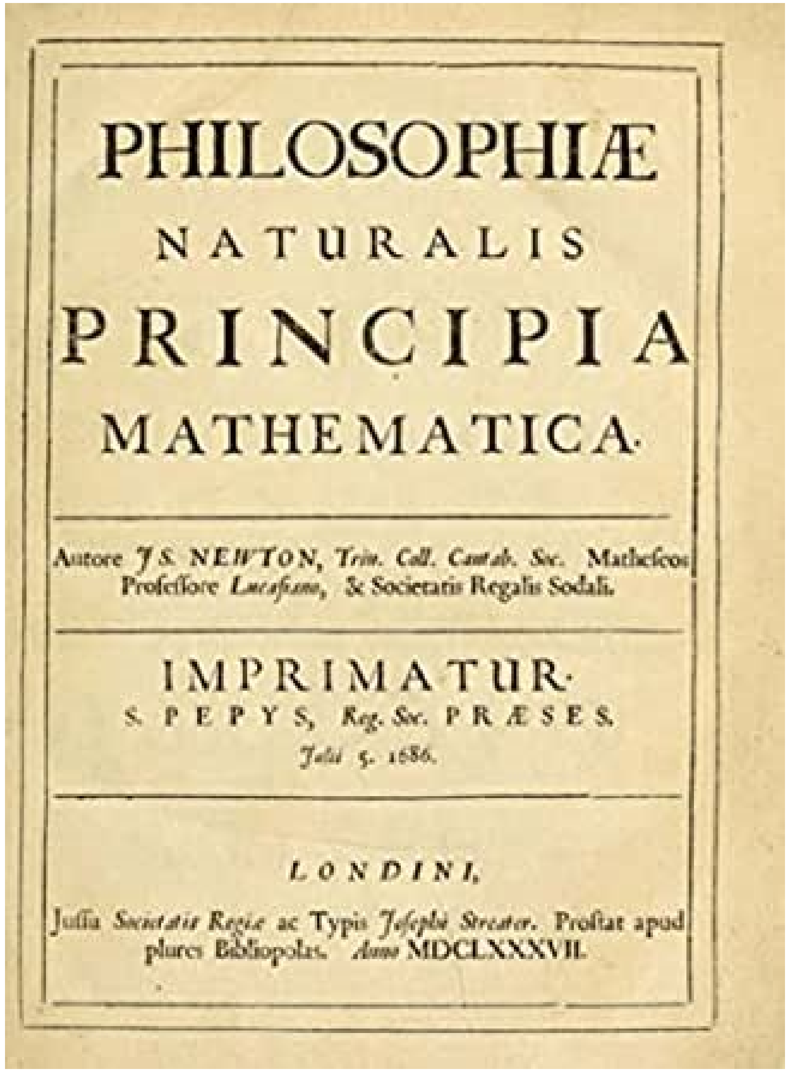
Nathaniel Bowditch (1773 – 1838)

Circumstances forced Bowditch to educate himself in his spare time after he was 10 years old, which he did with such zeal and ability that at age 21 he was unusually well informed and an outstanding mathematician.



US Navy Hydrographic Office

Nathaniel Bowditch (1773 – 1838)


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore J S. NEWTON, Trin. Coll. Cantab. Soc. Matheseos Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.

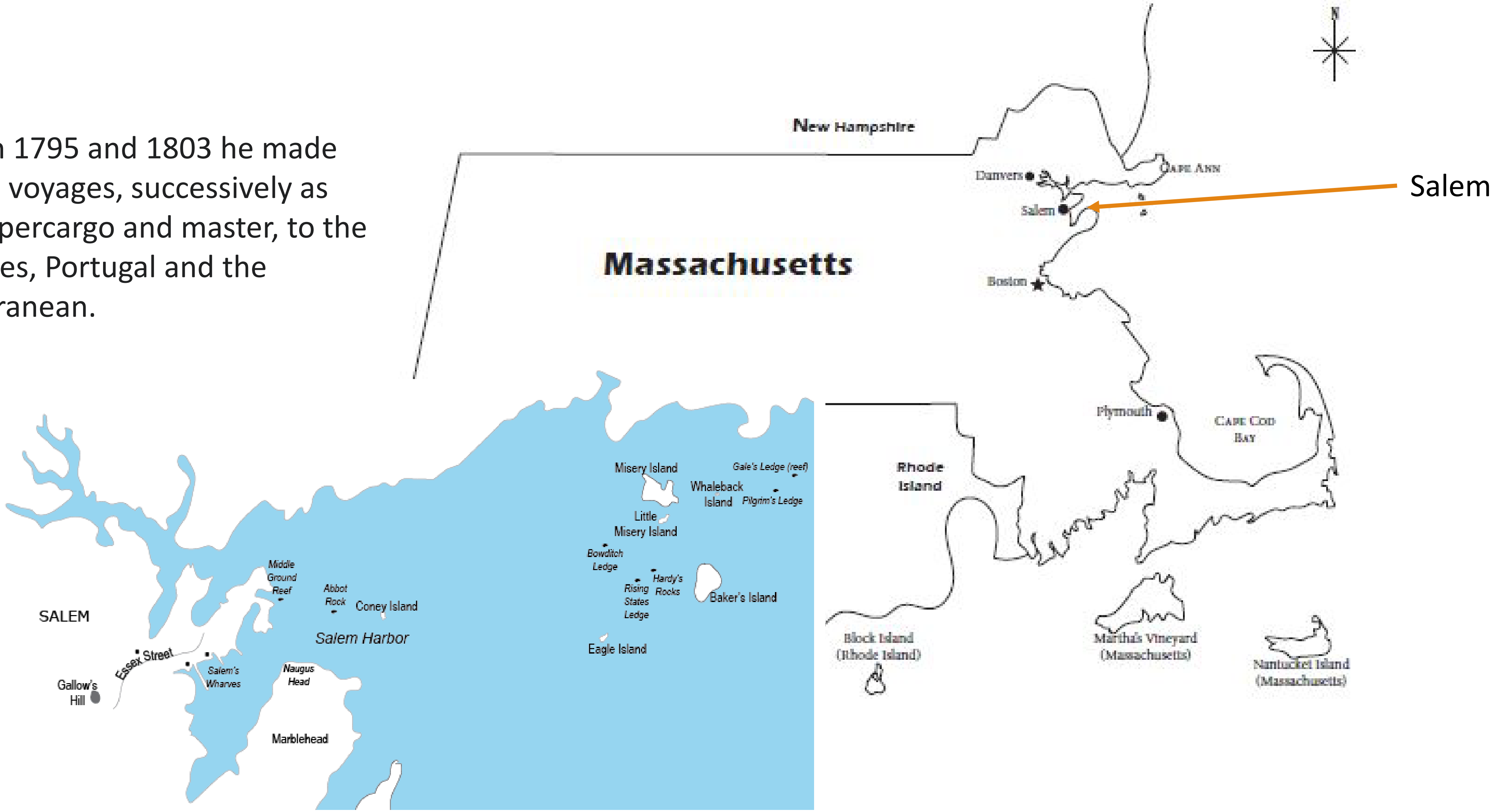
LONDINI,
Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

- An English sailor taught him the elements of navigation
- He began the study of Latin alone, that he might read the *Principia* of Isaac Newton
- and later in life he taught himself Spanish, Italian and German

Nathaniel I. Bowditch, *Memoir of Nathaniel Bowditch*, Boston, 1839

Voyages of Nathaniel Bowditch

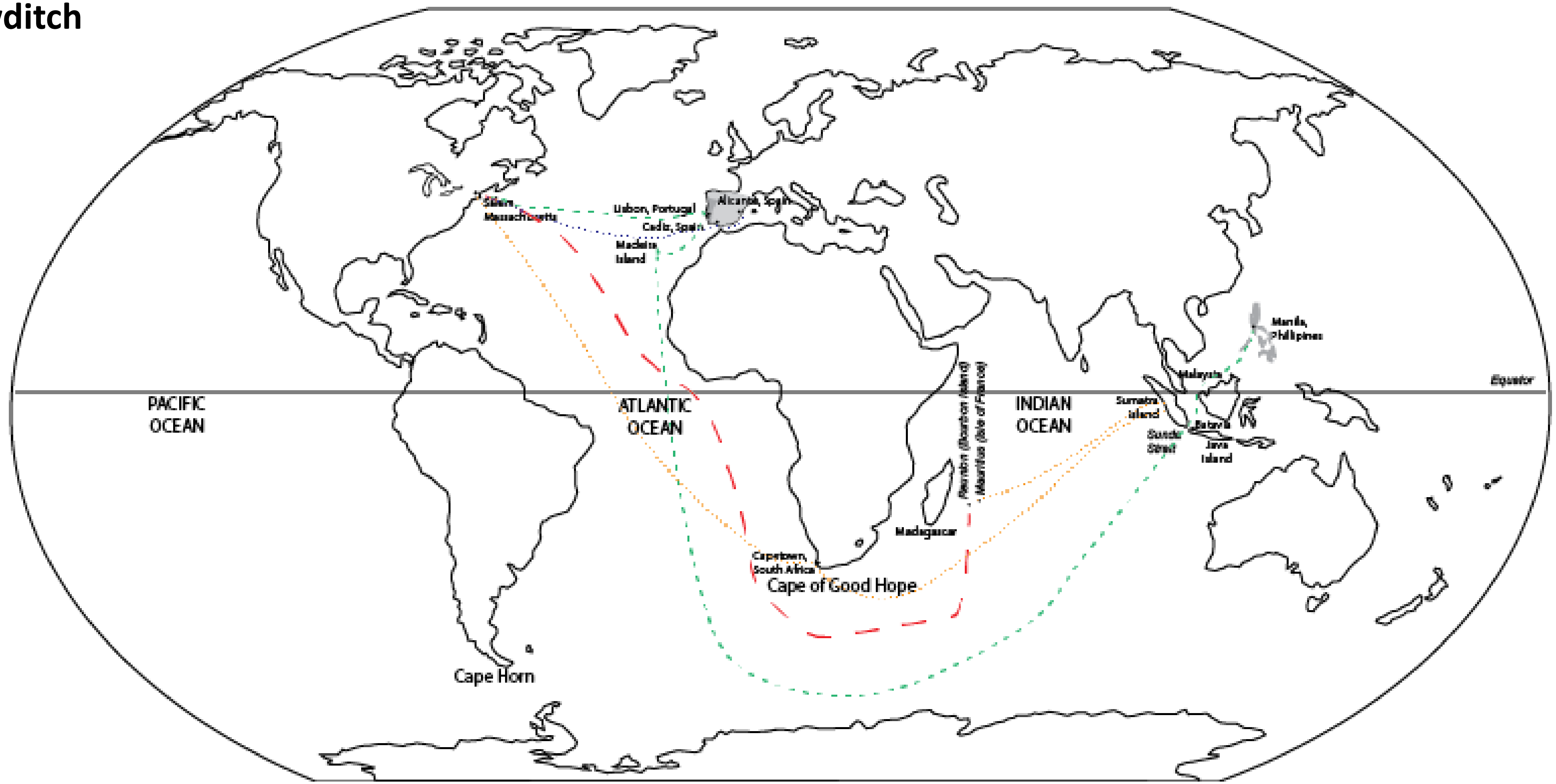
- Between 1795 and 1803 he made five long voyages, successively as clerk, supercargo and master, to the East Indies, Portugal and the Mediterranean.



Nathaniel I. Bowditch, *Memoir of Nathaniel Bowditch*, Boston, 1839

Voyages of Nathaniel Bowditch

- Sumatra
- Malaysia
- Philippines

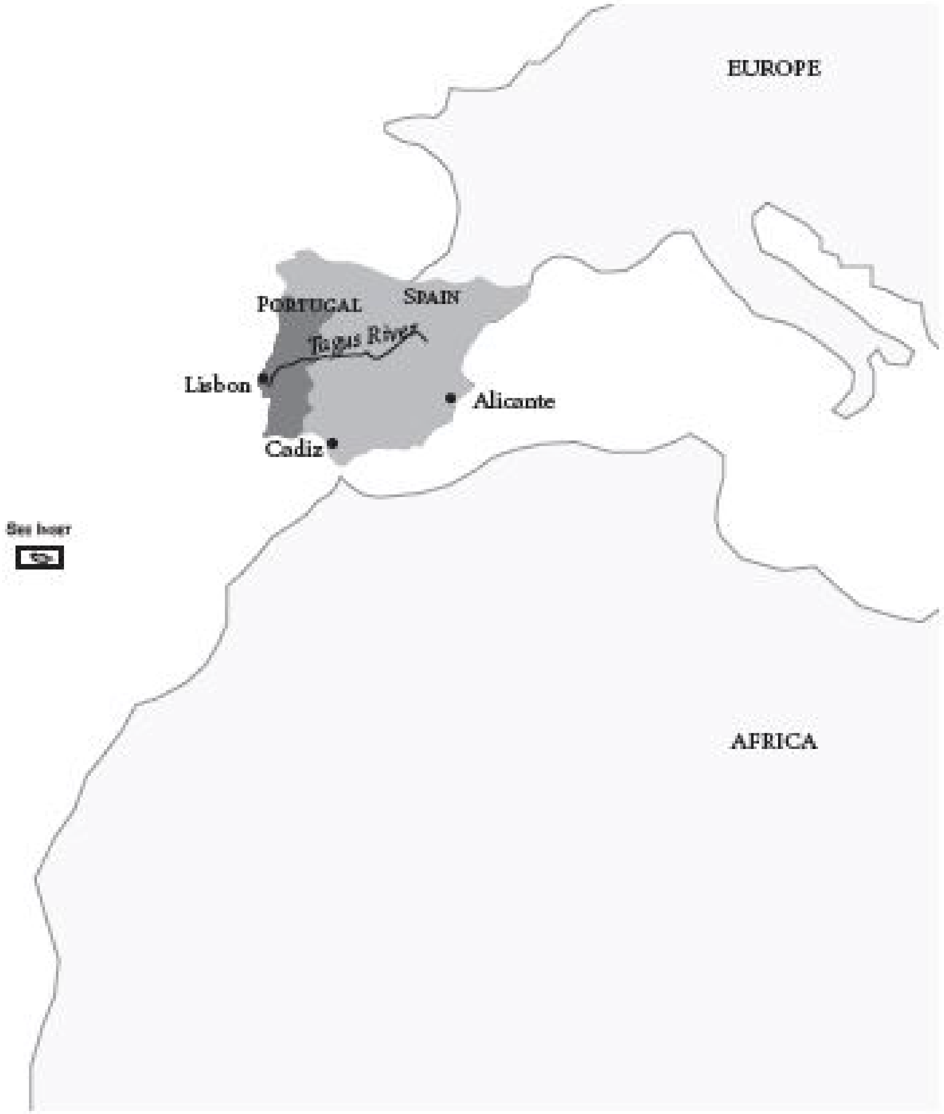


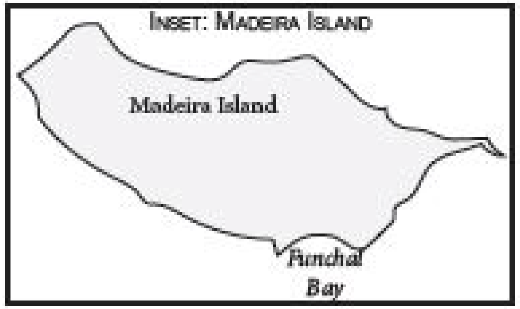
In 1795, Bowditch went to sea on his first of four voyages as supercargo and captain’s writer. A fifth voyage he made as master and part owner of a ship, returning to Salem in 1803, to retire to his studies and the insurance business.

US Navy Hydrographic Office

Voyages of Nathaniel Bowditch

- Madeira Island
- Portugal
- Spain

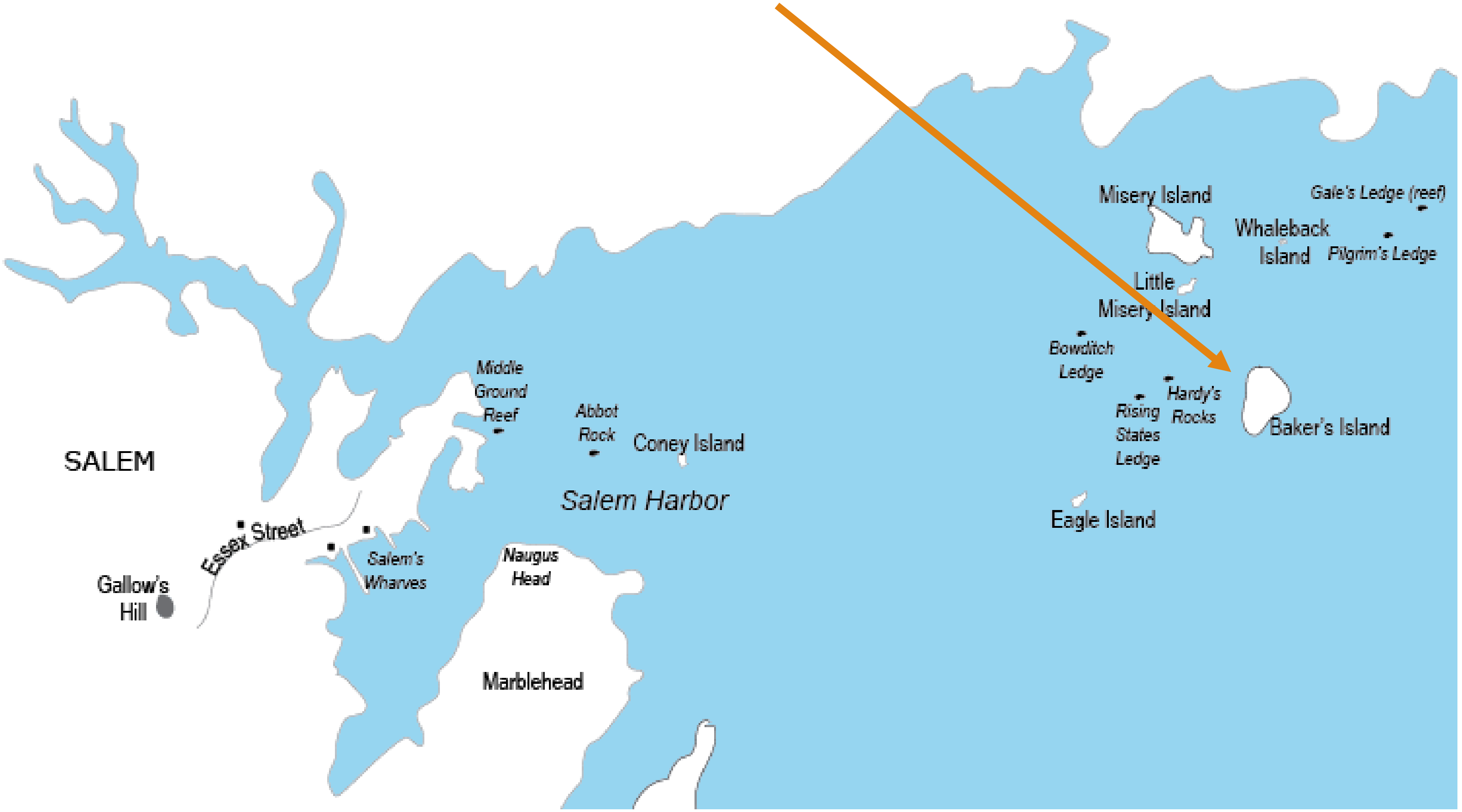




Nathaniel I. Bowditch, *Memoir of Nathaniel Bowditch*, Boston, 1839

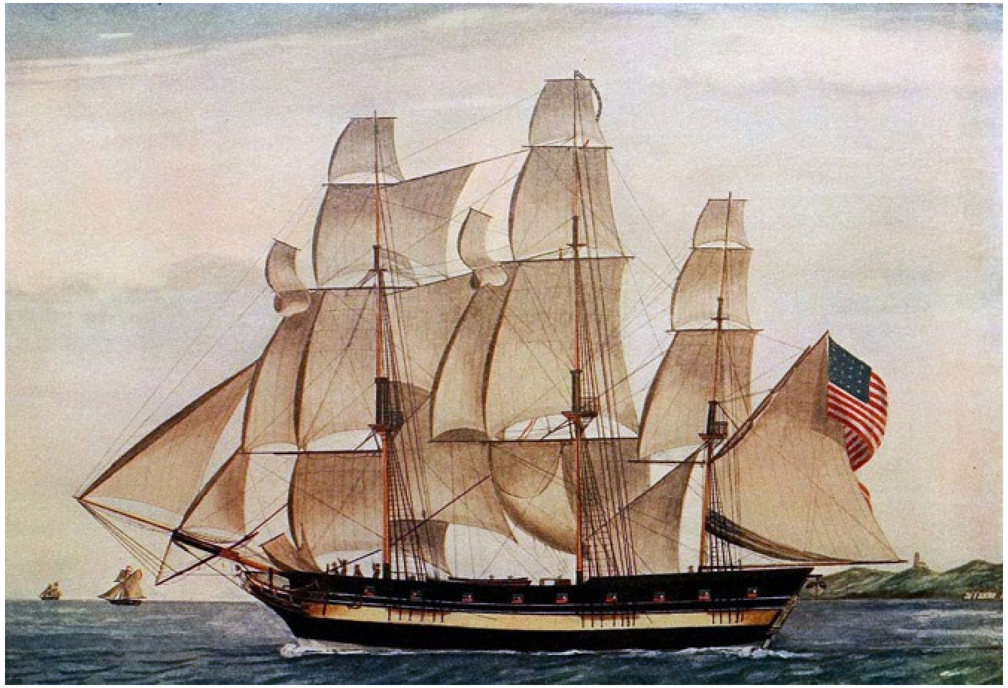
Nathaniel Bowditch (1773 – 1838)

On his return from his last voyage, he arrived off Salem by night in a violent snow storm, and with no other guide than his reckoning, confirmed by **a single glimpse of the light on Baker's island**, found his way safely into the harbor.



Nathaniel I. Bowditch, *Memoir of Nathaniel Bowditch*, Boston, 1839

Nathaniel Bowditch (1773 – 1838)

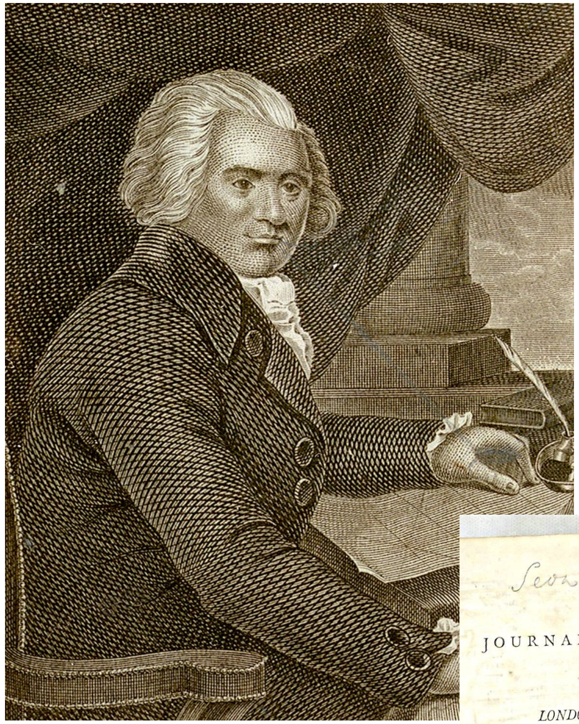


Early during these voyages, Bowditch became keenly interested in navigation and missed no opportunity to take observations of and to study the movements of celestial bodies. The most recent volume of navigation at the time was **Hamilton Moore's *Navigator***, published in London. Many errors were known to exist in this book. To have exact tables for his work, Bowditch commenced the laborious task of recomputing Moore's tables. He found the **book poorly arranged for practical navigation**, with inadequate tables and containing numerous errors.

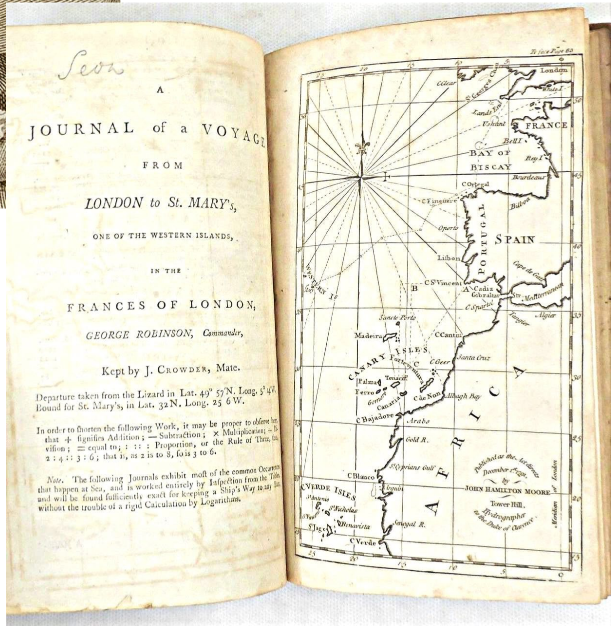
One error was said to be so serious as to have caused the loss of two ships at sea. When he communicated his findings to the American publisher of the book, Mr. Edmund Blunt of Newburyport, Massachusetts, who was about to publish a third edition in this country, Mr. Blunt urged Bowditch to take several copies of Moore's book on his next voyage to correct it for the third edition. The task involved such extensive revision that **Bowditch decided to write his own book** and to **"put down in the book nothing I can't teach the crew."** On that trip it is said that every man of the crew of 12, including the ship's cook, became able to take and calculate lunar observations and plot the daily position of the ship.

US Navy Hydrographic Office

Nathaniel Bowditch – home and business



John Hamilton Moore



Nathaniel Bowditch began his *New American Practical Navigator* (1802) as a project to **correct and extend the work of John Hamilton Moore**. In fact he published the first American edition of Moore's *Practical Navigator* in 1799, having collaborated with his brother on making corrections to Moore's work.

In fact Bowditch loved to carry out complex mathematical computations and the task of checking and correcting Moore's work was one he greatly enjoyed. He published a second edition in 1800, but by the time he came to publish a third edition he had changed Moore's book in such a major way that it was now sensible to publish the work under his own name which accounts for his 1802 publication.

Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

Nathaniel Bowditch – home and business

Although most of the errors were of little significance to practical navigation because they were errors in the fifth and sixth places of logarithm tables, **some errors were significant**.

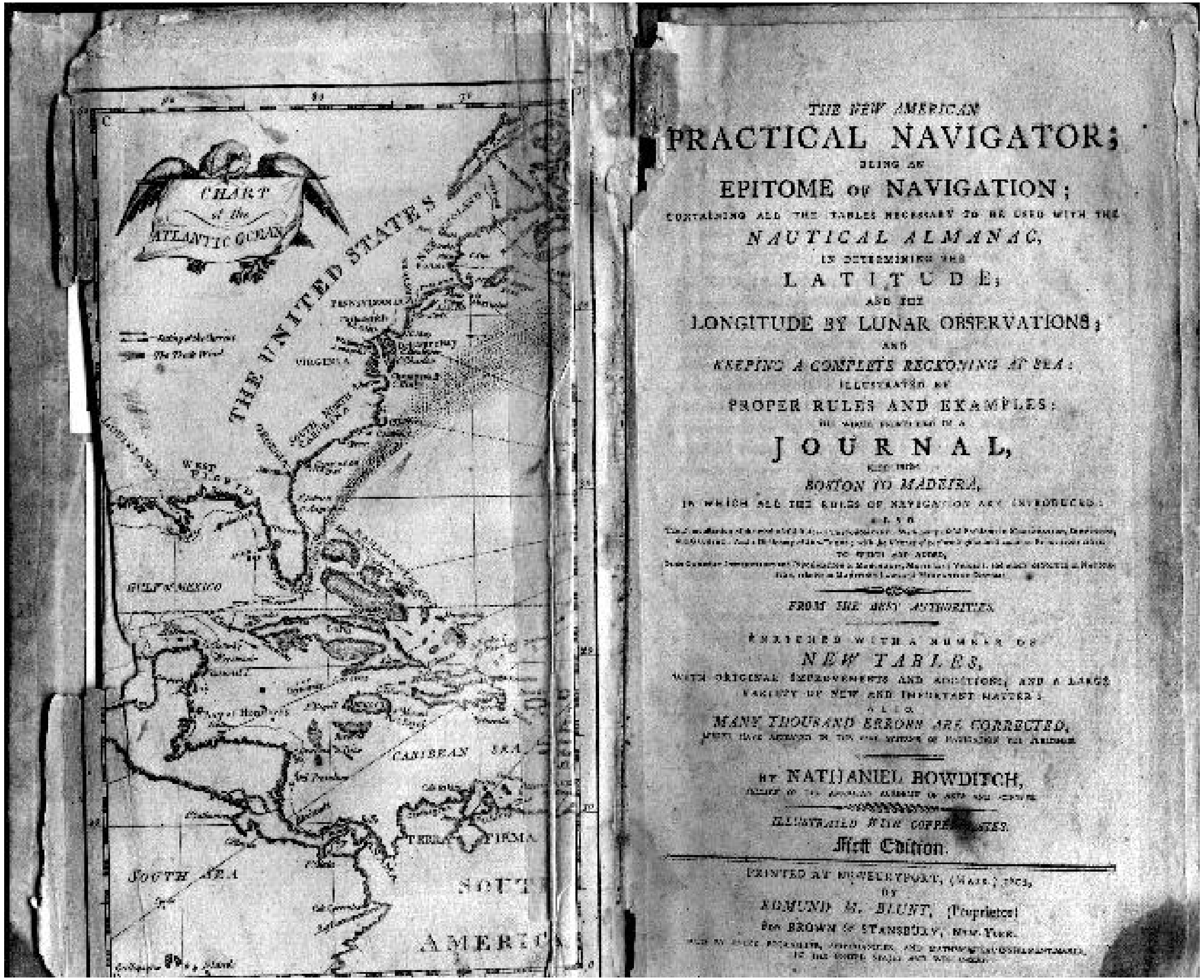
Nathaniel Bowditch – home and business

The most significant mistake was listing the year 1800 as a leap year in the table of the sun's declination.

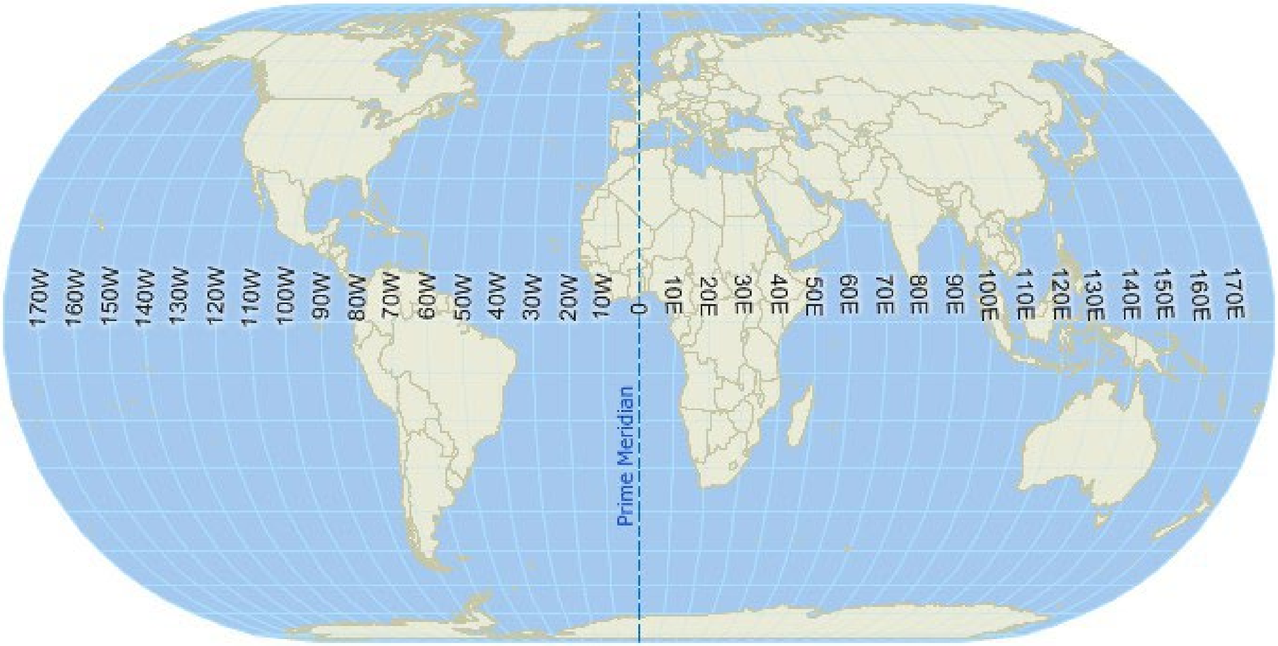
The consequence was that Moore gave the declination for March 1, 1800, as 7°11'.

Since the actual value was 7° 33', the calculation of a meridian altitude **would be in error by 22 minutes of latitude, or 22 nautical miles.**

Two ships were lost at sea as a result.



Nathaniel Bowditch – home and business

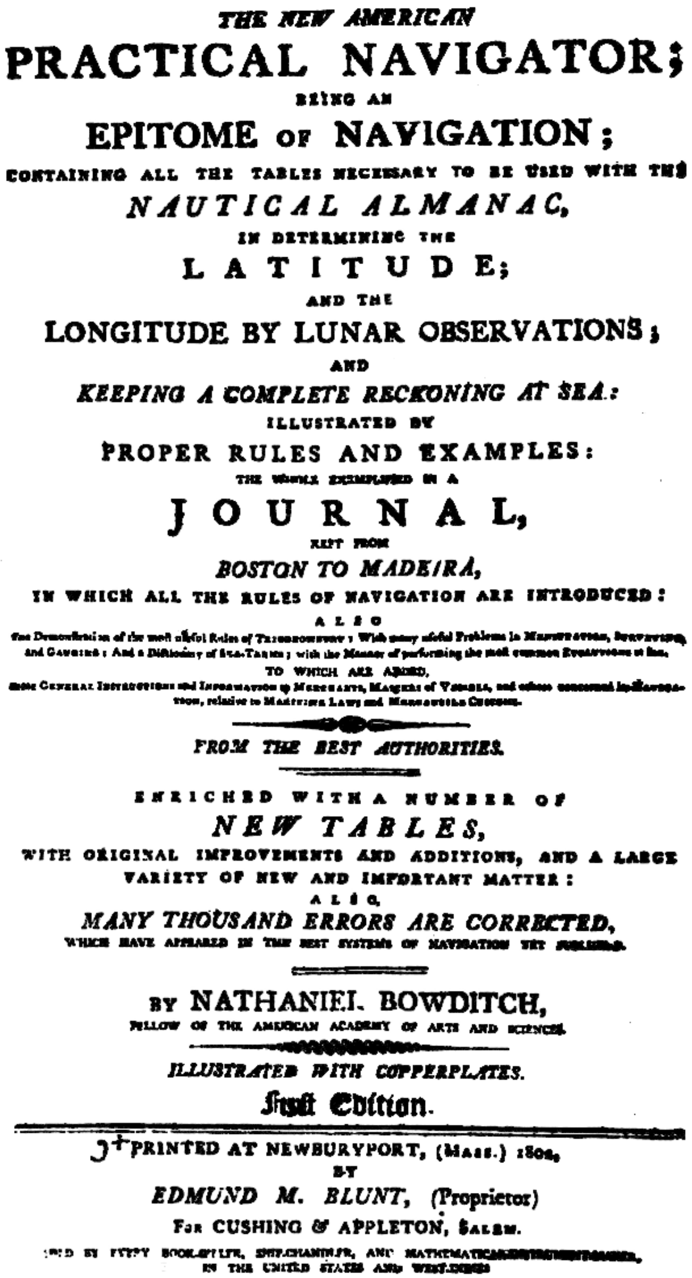


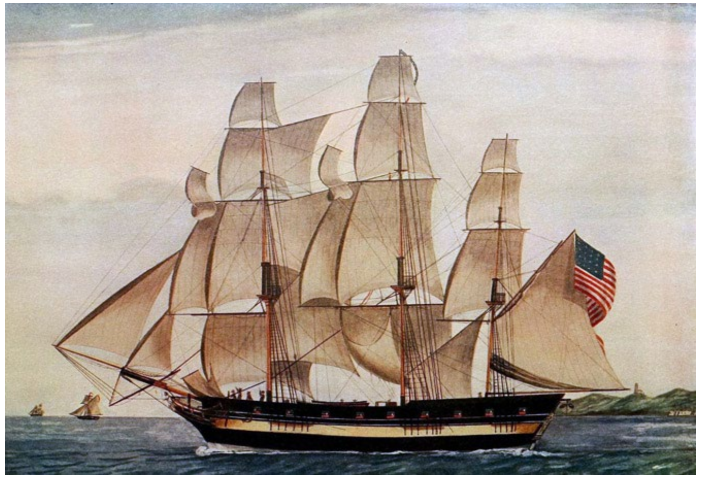
Bowditch's principal contribution to the first American edition was his chapter "**The Method of Finding the Longitude at Sea**," which discussed his new method for computing lunar distances. Following publication of the first American edition, Blunt obtained Bowditch's services in checking the American and English editions for further errors. Blunt then published a second American edition of Moore's thirteenth edition in 1800. **When preparing a third American edition for the press, Blunt decided that Bowditch had revised Moore's work to such an extent that Bowditch should be named as author.** The title was changed to ***The New American Practical Navigator*** and the book was published in 1802 as a first edition. Bowditch vowed while writing this edition to "put down in the book nothing I can't teach the crew," and it is said that every member of his crew including the cook could take a lunar observation and plot the ship's position.

Nathaniel Bowditch (1773 – 1838)

In 1802, Mr. Blunt published the first edition of the *American Practical Navigator*, which was received with such acclaim by the maritime world that over 30,000 copies in 10 editions were sold prior to Bowditch's death.

In 1866, the United States Hydrographic Office bought the copyright and since that time has published the book, revising it completely from time to time to keep step with the modern changes in navigation methods.

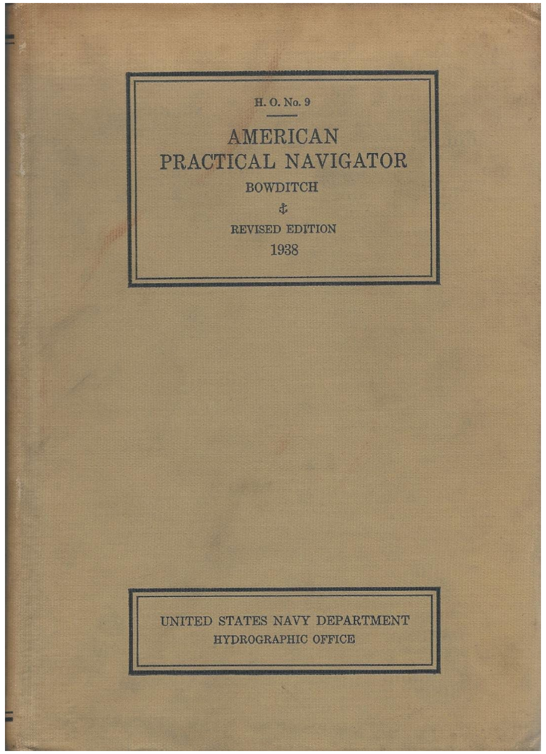

THE NEW AMERICAN
PRACTICAL NAVIGATOR;
BEING AN
EPITOME OF NAVIGATION;
CONTAINING ALL THE TABLES NECESSARY TO BE USED WITH THE
NAUTICAL ALMANAC,
IN DETERMINING THE
LATITUDE;
AND THE
LONGITUDE BY LUNAR OBSERVATIONS;
AND
KEEPING A COMPLETE RECKONING AT SEA:
ILLUSTRATED BY
PROPER RULES AND EXAMPLES:
THE WHOLE EXEMPLIFIED IN A
JOURNAL,
KEPT FROM
BOSTON TO MADEIRA,
IN WHICH ALL THE RULES OF NAVIGATION ARE INTRODUCED:
ALSO
TO WHICH ARE ADDED,
FROM THE BEST AUTHORITIES.
ENRICHED WITH A NUMBER OF
NEW TABLES,
WITH ORIGINAL IMPROVEMENTS AND ADDITIONS, AND A LARGE
VARIETY OF NEW AND IMPORTANT MATTER:
ALSO,
MANY THOUSAND ERRORS ARE CORRECTED,
WHICH HAVE APPEARED IN THE BEST SYSTEMS OF NAVIGATION YET PUBLISHED.
BY NATHANIEL BOWDITCH,
FELLOW OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES.
ILLUSTRATED WITH COPPERPLATES.
First Edition.
PRINTED AT NEWBURYPORT, (Mass.) 1802,
BY
EDMUND M. BLUNT, (Proprietor)
For CUSHING & APPLETON, Salem.
IN THE UNITED STATES AND WEST-INDIES



US Navy Hydrographic Office

My Dad – Walt Alfred, Chief Bosun's Mate of the USS Wasatch in World War II

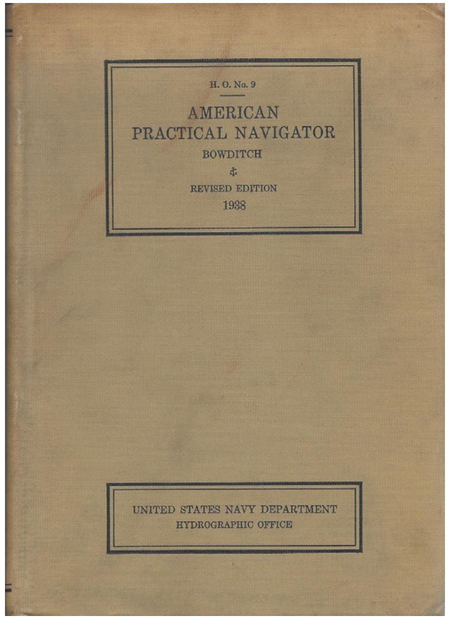
Nathanial Bowditch first published *American Practical Navigator* in 1802. The US Navy bought the copyright in 1867 for $25,000 and have published multiple editions, almost a million copies, in the last two centuries. **Bowditch combines the best technologies of each generation of navigator.** The newest edition includes the latest advances in electronic navigation, digital charting, celestial plotting and dead reckoning. Bowditch contains numerous tables which have been valued for years by practicing navigators. Bowditch is carried on the bridge of every US Navy ship.



My Dad used the 1938 edition of Bowditch to train the Wasatch crew in navigation:

- The practice of navigation at sea
- Compass error and dead reckoning
- Distance of an object by two bearings
- Winds, waves, tides and cyclonic storms
- Conversion table for nautical and statute miles
- Time, speed, distance and the Nautical Almanac
- Altitude corrections, latitude, longitude and azimuth

American Practical Navigator - Glossary



azimuth

- The **horizontal direction or bearing of a celestial point from a terrestrial point**, expressed as the angular distance from a reference direction. It is usually measured from 000° at the reference direction clockwise through 360°. An azimuth is often designated as true, magnetic, compass grid, or relative as the reference direction is true, magnetic, compass, or grid north, or heading, respectively.

nautical mile

- A unit of distance used principally in navigation. For practical consideration it is usually considered **the length of 1 minute of any great circle of the earth**, the meridian being the great circle most commonly used.

dead reckoning

- Determining **the position of a vessel by adding to the last fix the ship's course and speed for a given time.** The position so obtained is called a DEAD RECKONING POSITION. Comparison of the dead reckoning position with the fix for the same time indicates the sum of currents, winds, and other forces acting on the vessel during the intervening period.

Latitude - Angular distance from a primary great circle or plane.

Terrestrial latitude

- The angular distance from the equator, **measured northward or southward through 90°** and labeled N or S to indicate the direction of measurement

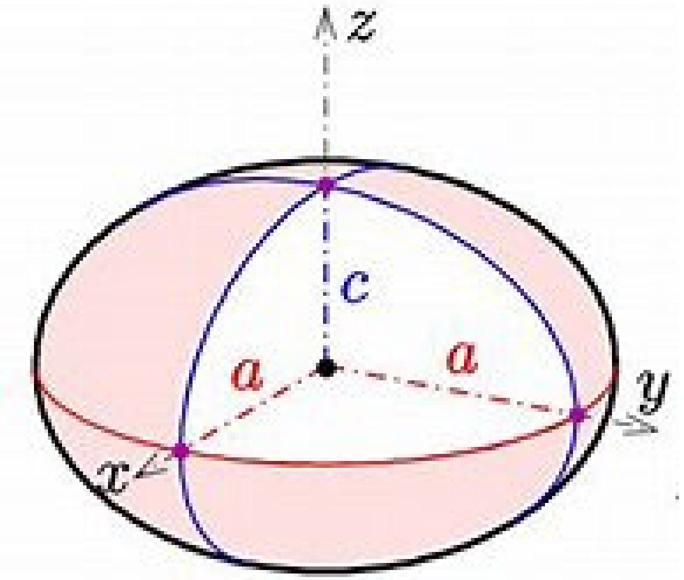
Astronomical latitude

- The angular distance between the plumb line and the plane of the celestial equator

Latitude - Angular distance from a primary great circle or plane.

Geocentric latitude

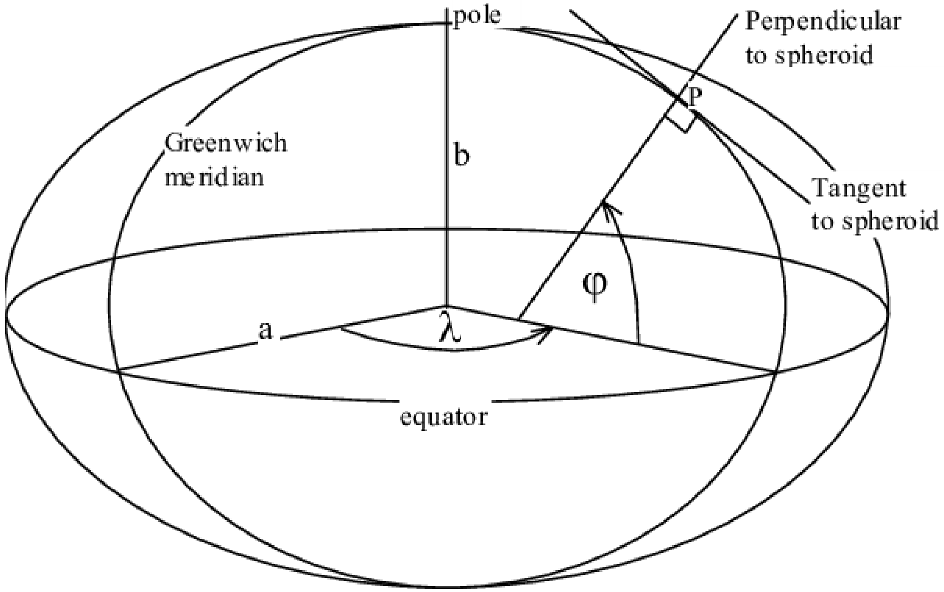
- The angle at the center of the reference ellipsoid between the celestial equator and a radius vector to a point on the ellipsoid.



Latitude - Angular distance from a primary great circle or plane.

Geodetic or topographical **latitude**

- The **angular distance between the plane of the geodetic equator and a normal to the ellipsoid. Geodetic latitude is used for charts**.

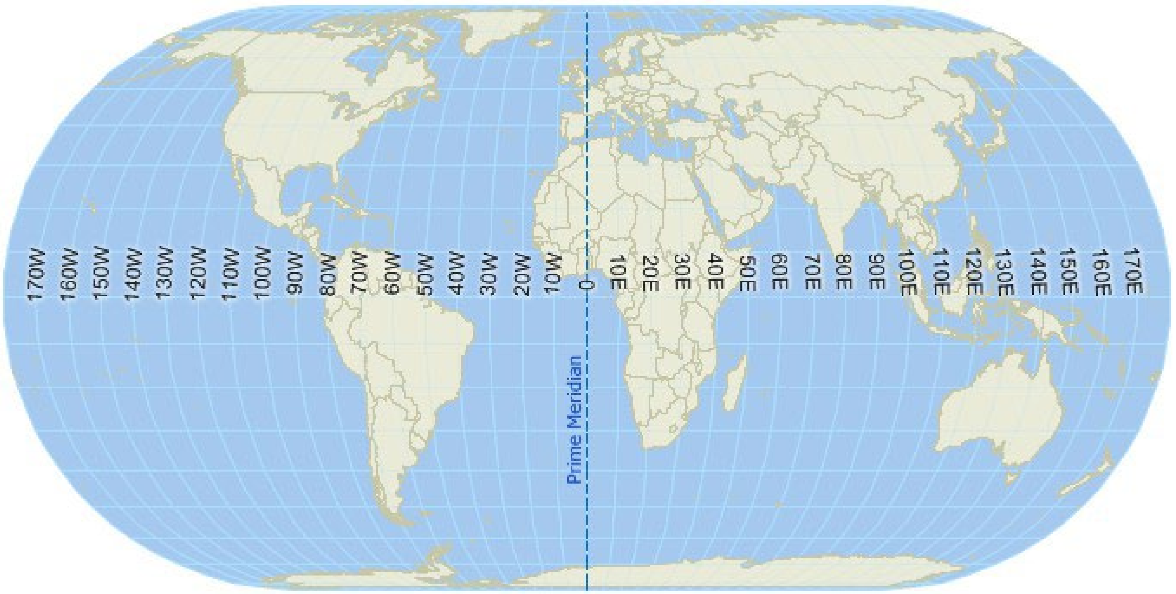


Geodetic latitude 

Geodetic longitude 

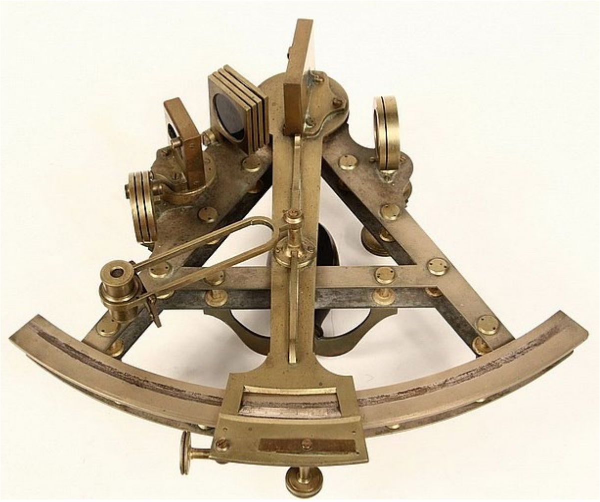
American Practical Navigator - Glossary

Longitude - Angular distance, along a primary great circle, from the adopted reference point.



- **Terrestrial longitude** is the arc of a parallel, or the angle at the pole, between the prime meridian and the meridian of a point on the earth **measured eastward or westward** from the prime meridian through 180° and labeled E or W to indicate the direction of measurement.
- Astronomical longitude is the angle between the plane of the prime meridian and the plane of the celestial meridian
- **Geodetic longitude is the angle between the plane of the geodetic meridian and a station and the plane of the geodetic meridian at Greenwich.** Geodetic and sometimes astronomical longitude are also called geographic longitude. **Geodetic longitude is used in charting.**
- Assumed longitude is the longitude at which an observer is assumed to be located for an observation or computation.
- Observed longitude is determined by one or more lines of position extending in a generally north-south direction.
- Celestial longitude is angular distance east of the vernal equinox, along the ecliptic.

Chapter XVI - The practice of navigation at sea



1800s sextant

The following program represents a minimum of work and celestial observations that should be accomplished daily at sea during clear weather in order to keep a continuous accurate record of the position of the ship. Cloudy and overcast weather may, at any time, reduce this program, in which case the dead reckoning must be relied upon.

1. Departure and **continuous dead reckoning plot of position**.
2. Star observations during morning twilight, for a fix from two or more lines of position.
3. Sun observation on or near prime vertical for longitude, or at other time for line of position.
4. **Azimuth observation of the sun to find compass error**, either in conjunction with sun sight or as a separate time azimuth observation.
5. Computation of the interval to noon, watch time of local apparent noon, and constants for meridian or ex-meridian sights.
6. Meridian or ex-meridian observation of the sun for noon latitude line. Running fix or cross with Venus line for noon fix. Determine the day’s run, the set and drift of current since the previous noon.
7. **At least one sun observation during the afternoon** for use in case the stars are not available at twilight.
8. Azimuth observation of sun for star error.
9. **Star observations during twilight** for a fix from two or more lines of position.

Chapter XVI - The practice of navigation at sea

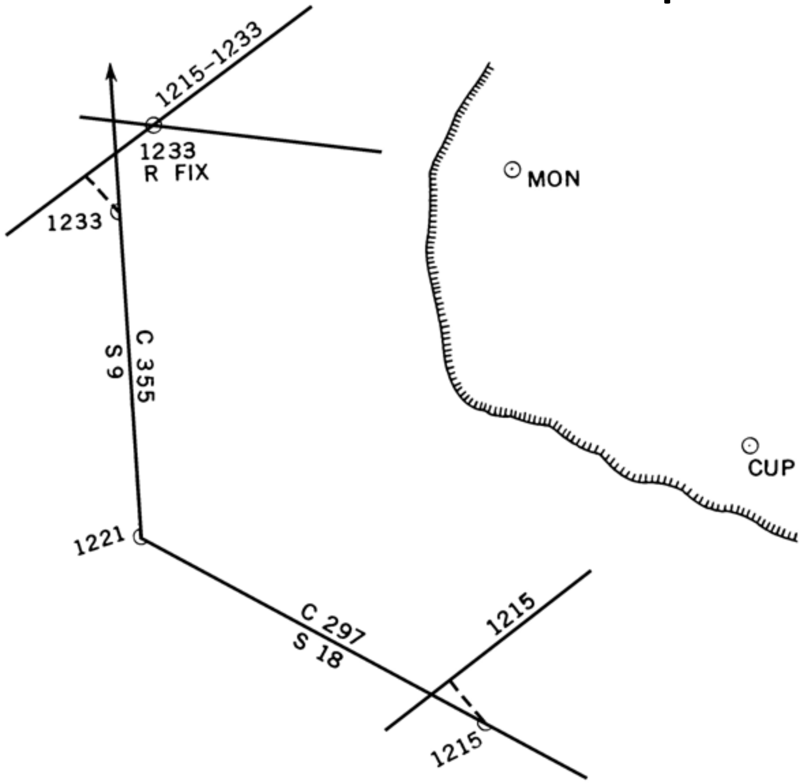


Figure 812f. A running fix with a change of course and speed between observations on separate landmarks.

812. The Running Fix

When only one navigational aid (NAVAID) is available from which to obtain bearings, use a technique known as the **running fix**. Use the following method:

1. Plot a bearing to a NAVAID, line of position 1 (LOP 1)
2. Plot a second bearing to a NAVAID (either the same NAVAID or a different one) at a later time (LOP 2)
3. Advance LOP 1 to the time when LOP 2 was taken
4. The intersection of LOP 2 and the advanced LOP 1 constitutes the running fix

Chapter VI – Compass error

Since **the magnetic poles of the Earth do not coincide with the geographic poles**, a compass needle in line with the Earth's magnetic field will not indicate true north, but magnetic north. The angular difference between the true meridian (great circle connecting the geographic poles) and the magnetic meridian (direction of the lines of magnetic flux) is called **variation**. This variation has different values at different locations on the Earth. These values of magnetic variation may be found on pilot charts and on the compass rose of navigational charts.

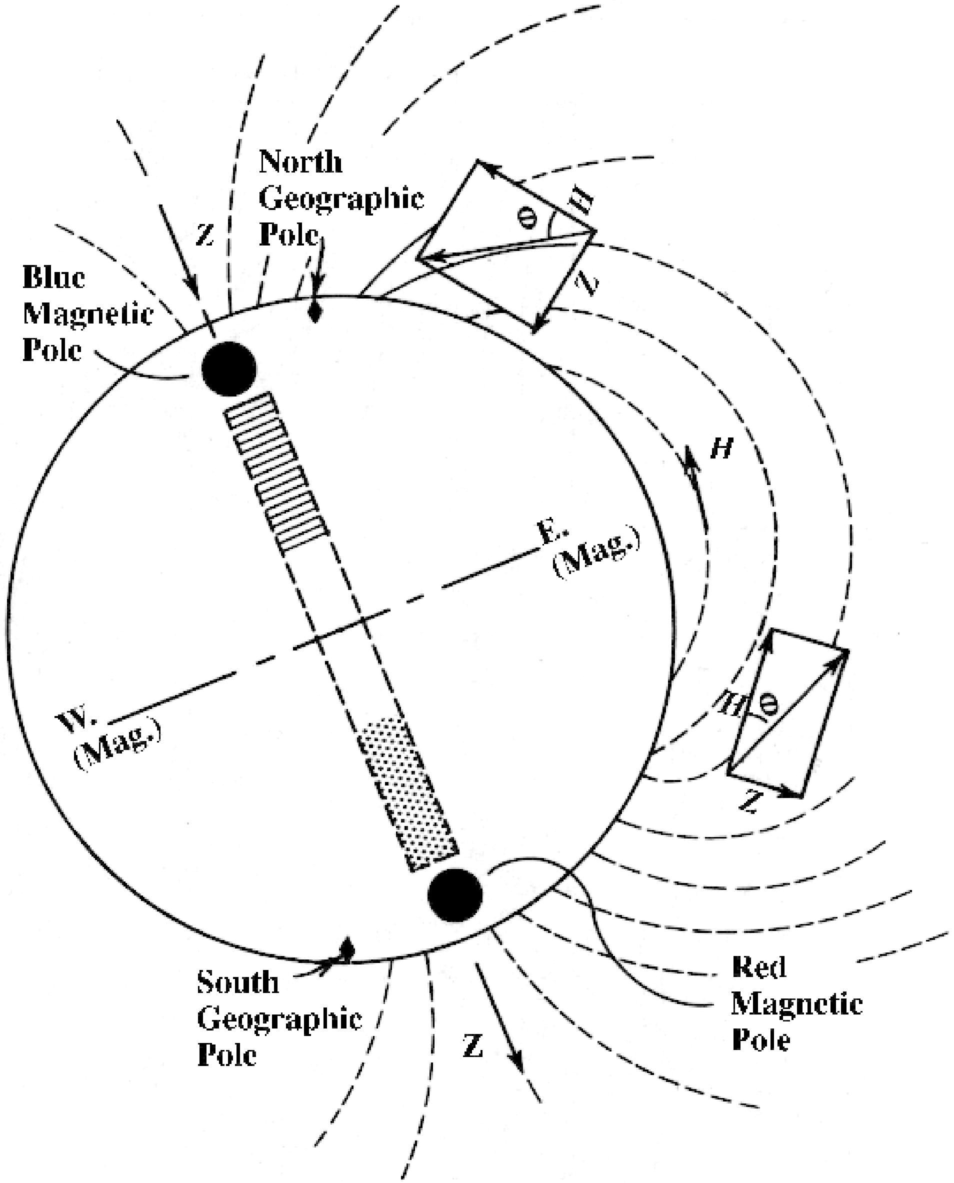


Figure 602a Terrestrial magnetism

Chapter VI – Compass error

The poles are not geographically static. They are known to migrate slowly, so that variation for most areas undergoes a small annual change, the amount of which is also noted on charts.

Figure 602b and Figure 602c show magnetic dip and variation for the world.
Up-to-date information on geomagnetics is available at http://geomag.usgs.gov

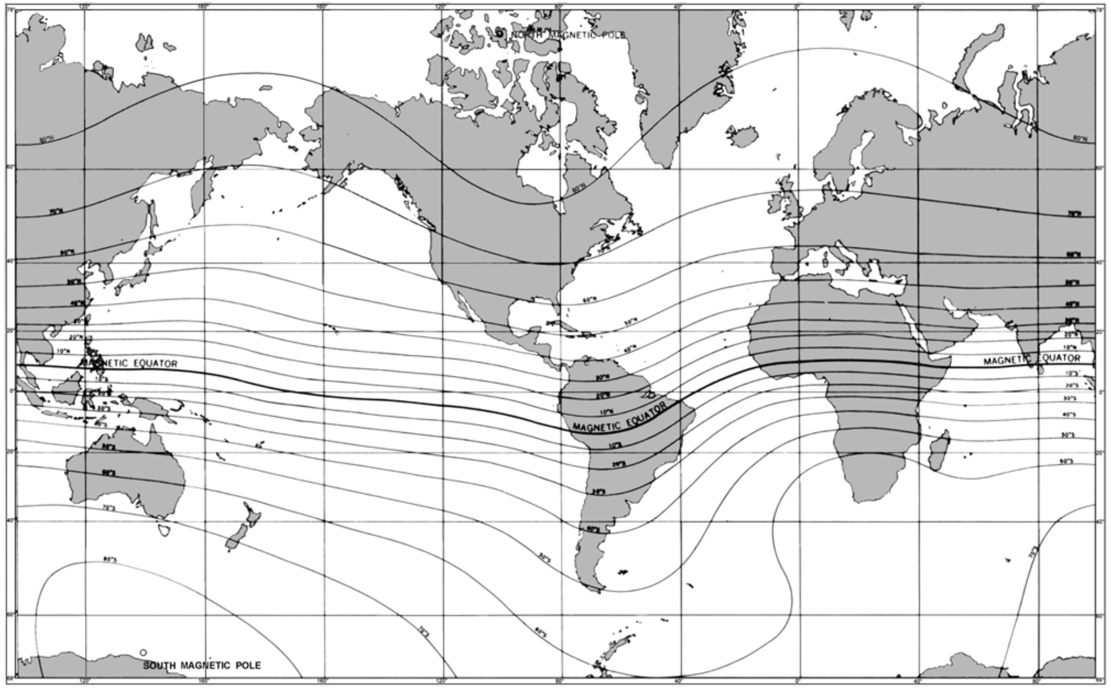


Figure 602b. Magnetic dip for the world

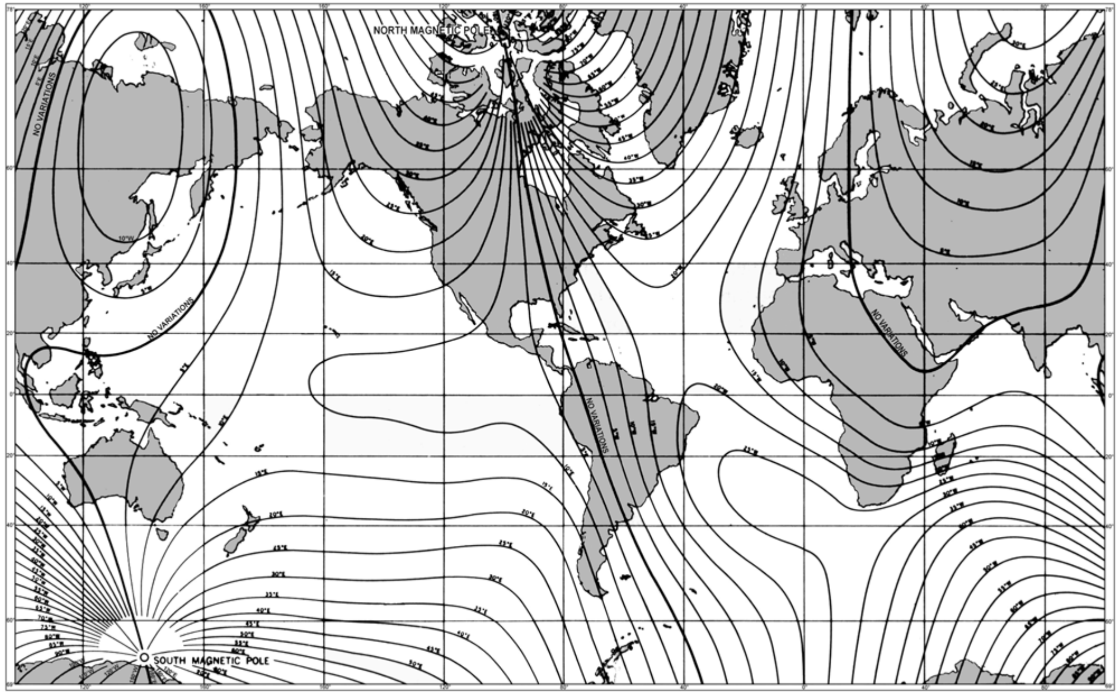
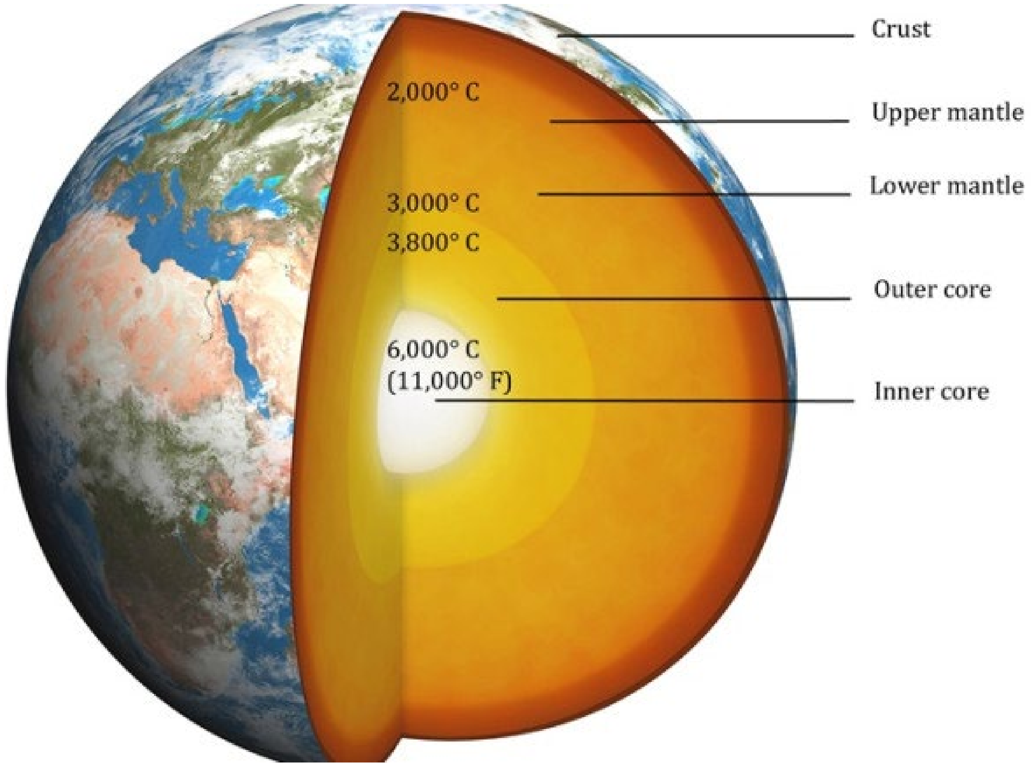
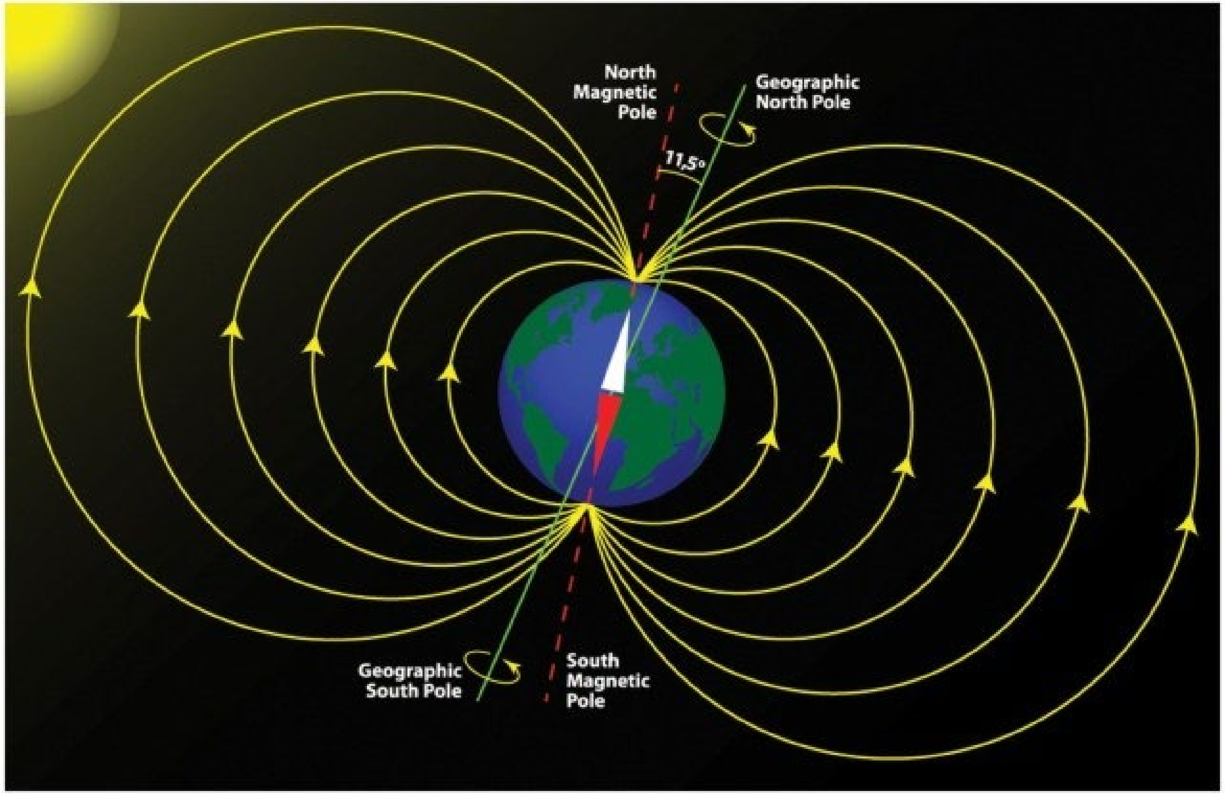


Figure 602c. Magnetic variation for the world





Earth's north and south poles periodically swap locations, with the **last flip happening about 780,000 years ago**.

Chapter VII – Dead reckoning

Dead reckoning (DR) is **the process of determining one's present position by projecting course(s) and speed(s)** from a known past position and predicting a future position by projecting course(s) and speed(s) from a known present position. The DR position is only an approximate position because it does not allow for the effect of leeway, current, helmsman error or compass error.

Dead reckoning helps:

- in determining sunrise and sunset
- in predicting landfall, sighting lights and predicting arrival times
- in evaluating the accuracy of electronic positioning information
- in predicting which celestial bodies will be available for future observation
- **in projecting the position of the ship into the immediate future and avoiding hazards to navigation**

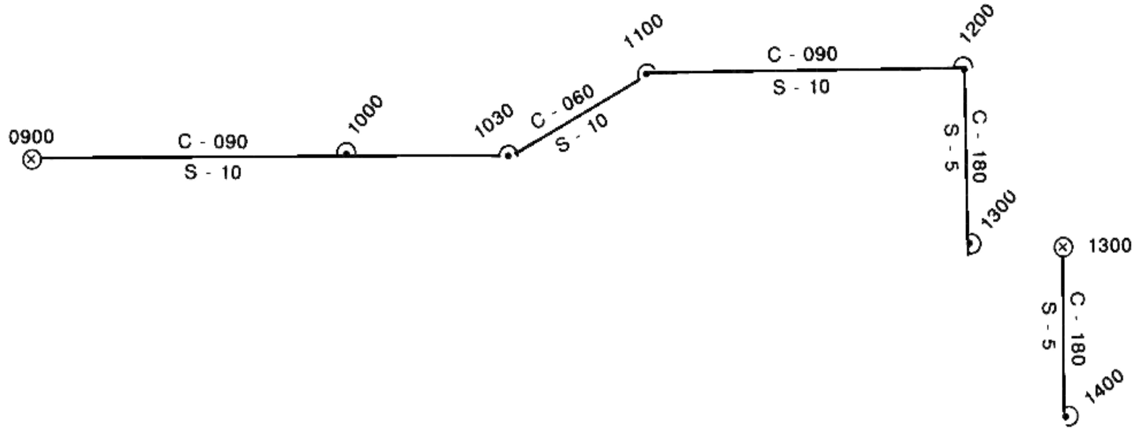


Figure 703. A typical dead reckoning plot

Chapter VIII – Distance of an object by two bearings

Geometrical relationships can define a running fix.

In Figure 821:

- At A, the navigator takes a bearing on NAVAID D. The bearing is expressed as degrees right or left of course
- later, at B, he takes a second bearing to D
- similarly, he takes a bearing at C, when the landmark is broad on the beam.
- The navigator knows the angles at A, B, and C and the distance run between points.

The various triangles can be solved using Table 18.

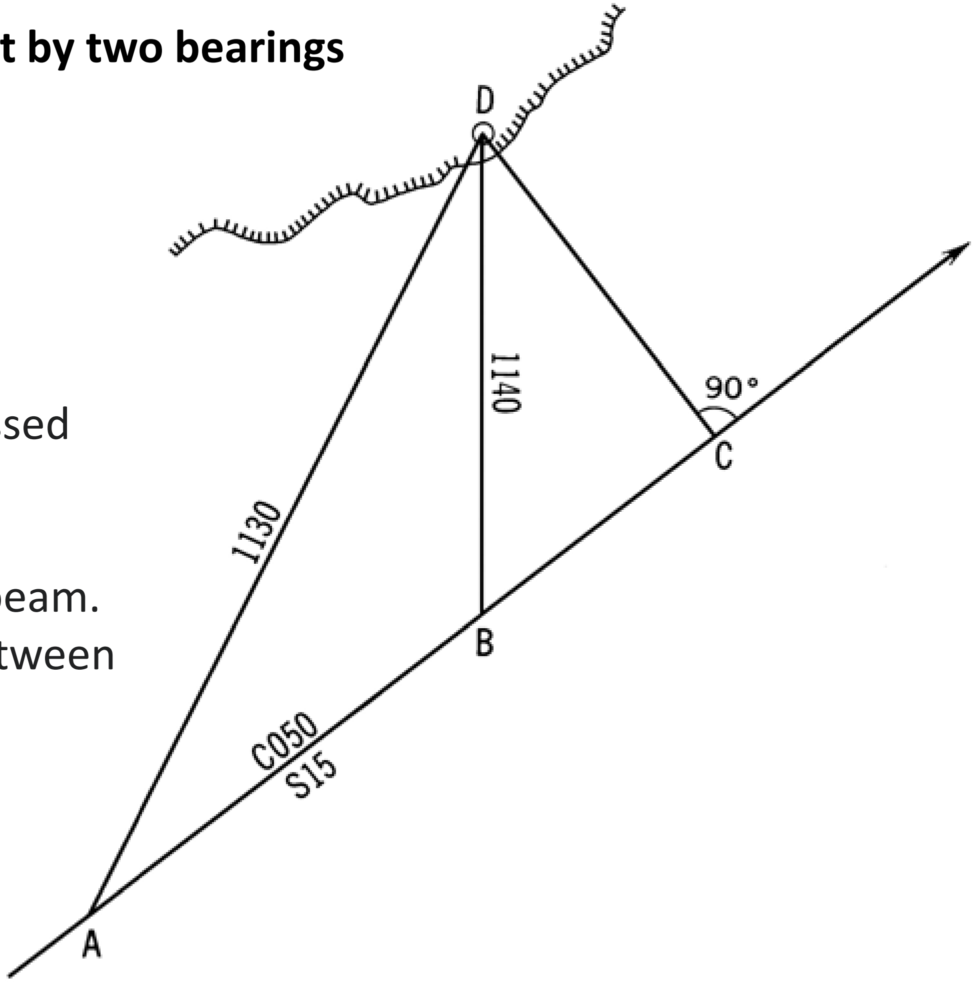


Figure 821. Triangles involved in a Table 18 running fix.

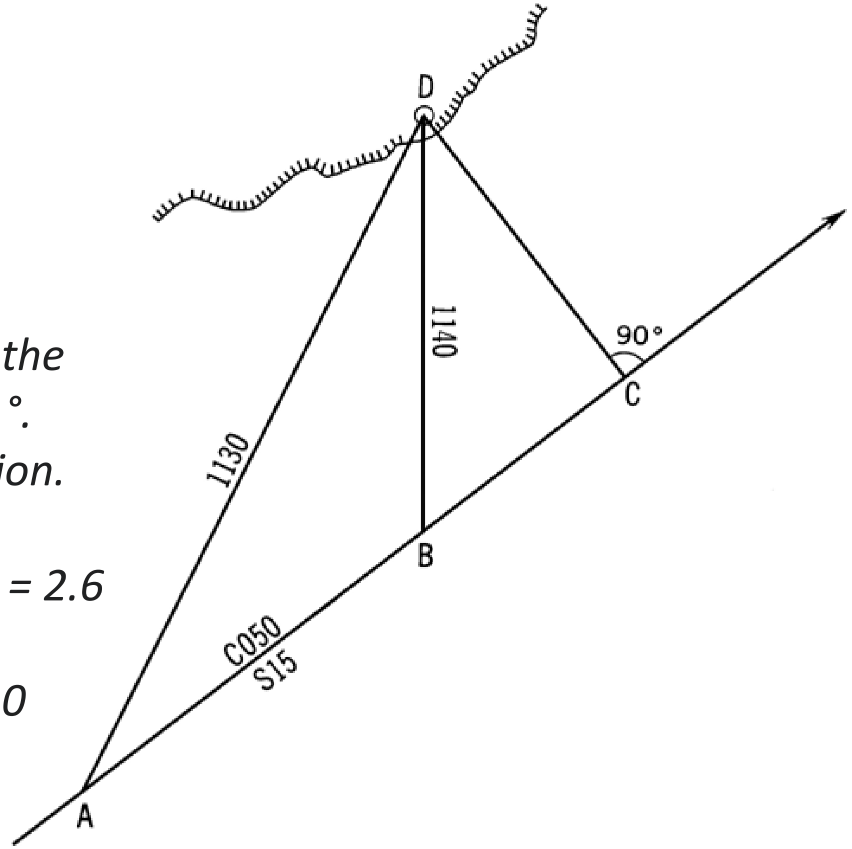
Chapter VIII – Distance of an object by two bearings

Example: *A ship is steaming on course 050°, speed 15 knots. At 1130 a lighthouse bears 024°, and at 1140 it bears 359°.*

Required:

A. Distance from the light at 1140.

B. Distance from the light when it is broad on the port beam.



Solution:

1. *The difference between the course and the first bearing (050° – 24°) is 26°, and the difference between the course and the second bearing (050° + 360° - 359°) is 51°.*
2. *From Table 18, the two numbers (factors are 1.04 and 0.81, found by interpolation.*
3. *The distance run between bearings is 2.5 miles (10 minutes at 15 knots).*
4. *The distance from the lighthouse at the time of the second bearing is 2.5 × 1.04 = 2.6 miles.*
5. *The distance from the lighthouse when it is broad on the beam is 2.5 × 0.81 = 2.0 miles.*

Answer: (A) D 2.6 miles (B) D 2.0 miles

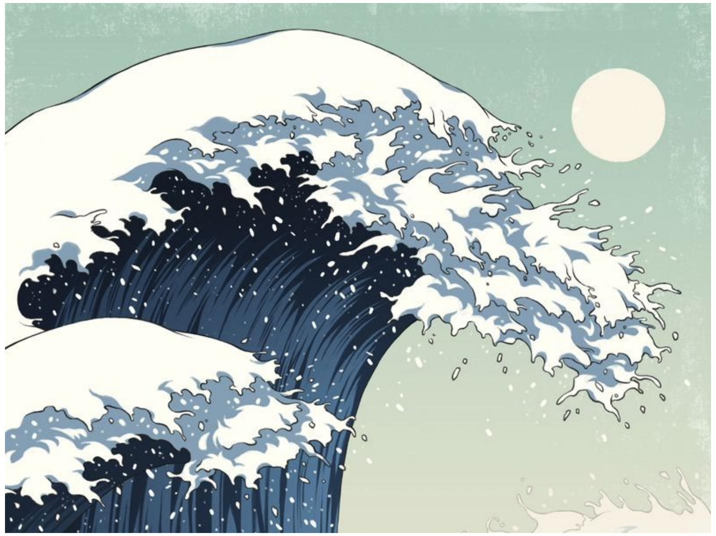
This method yields accurate results only if the helmsman steers a steady course and the navigator uses the vessel's speed

Chapter XXXII – Winds, waves, tides and cyclonic storms

3200. Introduction

Ocean waves, the most easily observed phenomenon at sea, are probably the least understood by the average seaman. More than any other single factor, ocean waves are likely to cause a navigator to change course or speed to avoid damage to ship and cargo. **Wind-generated ocean waves have been measured at more than 100 feet high**, and tsunamis, caused by earthquakes, far higher. A mariner with knowledge of basic facts concerning waves is able to use them to his advantage, avoid hazardous conditions, and operate with a minimum of danger if such conditions cannot be avoided.

100-foot wave in the North Sea



Biggest Waves

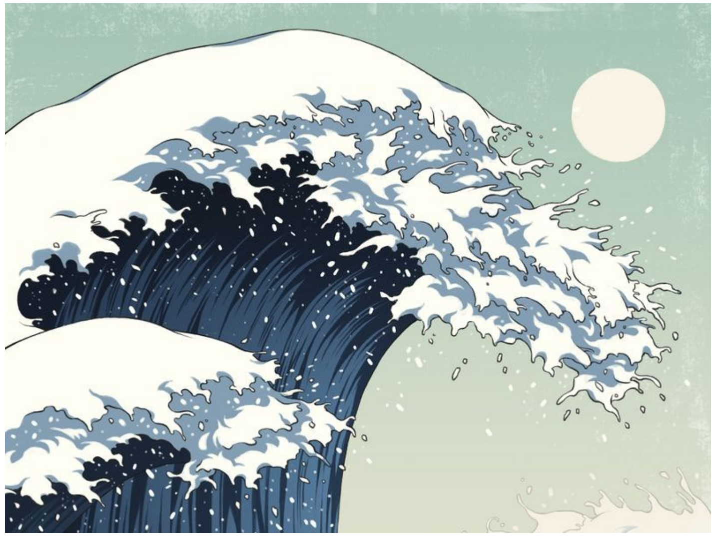
25 feet
Teahupo'o, Tahiti's waves are modest in height but surfers call the thick lips the world's "heaviest."

29 feet
As the tide comes in on Hangzhou, China, a wave called the Silver Dragon travels up the Qiantang River, opposite the direction of the river's flow. This tidal bore is largest in September.

30 feet
The Banzai Pipeline in Oahu, Hawaii, gets our vote for the most dangerous surf wave. It tosses boarders directly into a shallow reef. At least ten people are believed to have died there.

50 feet
The Indian Ocean tsunami in 2004 traveled at speeds reaching 500 miles per hour and barged up to a mile inland. It killed some 200,000 people, making it the deadliest wave known.

Kayla Elam, Smithsonian Magazine, September 2014



Biggest Waves

78 feet

Garrett McNamara holds the record for the largest wave ever surfed, set in 2011 in Nazare, Portugal. In 2013, he claimed to have surfed a 100-footer also at Nazare, but the height hasn't been confirmed.

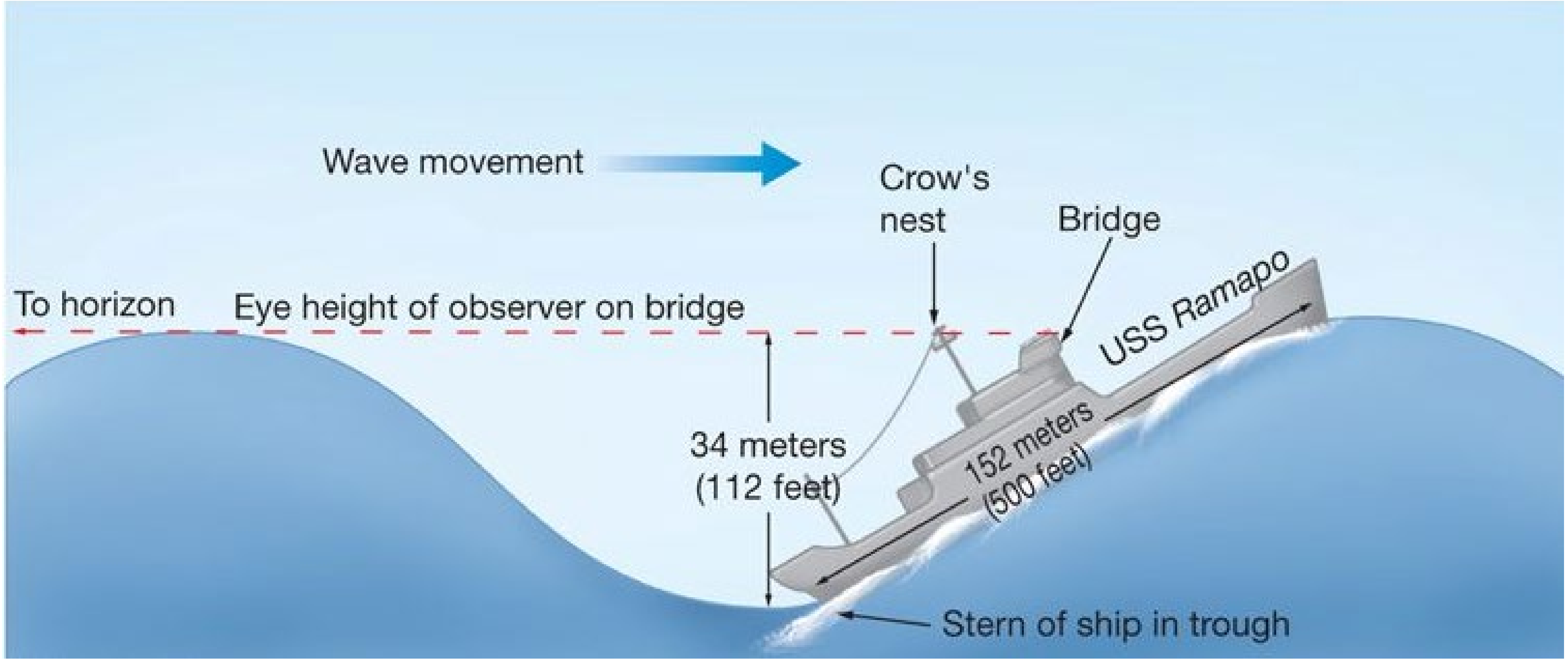
84 feet

Until 1995, most scientists dismissed sudden, unexpected swells known as rogue waves as maritime myth. But on New Year's Day of that year, a monitoring platform off Norway's coast recorded a single 84-foot wave surrounded by 20-footers. The simplest explanation for these monsters is that two or more waves meet and align in such a way that their crests combine into one much larger crest.

100 feet

An earthquake followed by a landslide in 1958 in Alaska's Lituya Bay generated a wave 100 feet high, the tallest tsunami ever documented. When the wave ran ashore, it snapped trees 1,700 feet upslope. Five deaths were recorded, but property damage was minimal because there were few cities or towns nearby.

Kayla Elam, Smithsonian Magazine, September 2014



The highest wave ever reliably reported was 112 feet observed from the USS Ramapo in 1933.

- Waves 500 feet long, 112 feet high

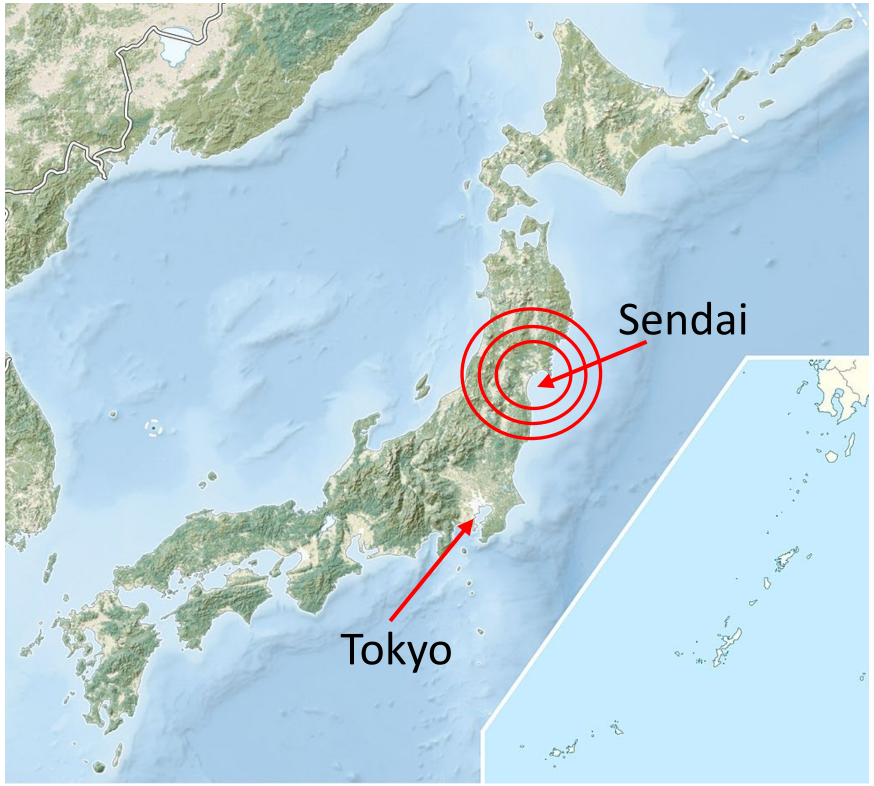
Nathaniel Bowditch, *American Practical Navigator,* United States Government Printing Office, Washington, 2020

11 March 2011, Great Tōhoku Earthquake

The **2011 earthquake off the Pacific coast of Tōhoku**
Japanese: 東北地方太平洋沖地震, *Tōhoku-chihō Taiheiyō Oki Jishin*

was a magnitude 9.0–9.1 earthquake with epicenter approximately 70 kilometers (43 miles) east of the Oshika Peninsula of **Tōhoku**

It was the most powerful earthquake ever recorded in Japan and the fourth most powerful in the world since modern record-keeping began in 1900. The earthquake triggered **powerful tsunami waves that may have reached heights of up to 40.5 meters (133 feet) in Miyako** in Tōhoku's Iwate Prefecture and which, in the Sendai area, traveled at 700 km/h (435 mph) and up to 10 km (6 miles) inland. Residents of Sendai had only eight to ten minutes of warning, and more than a hundred evacuation sites were washed away.



Richard A. Clarke; R.P. Eddy, *Warnings: Finding Cassandras to stop catastrophe,* Harper Collins, 2017

Chapter XXXII – Winds, waves, tides and cyclonic storms

3201. Causes of Waves

Waves on the surface of the sea are caused

- principally by wind, but other factors,
- such as submarine earthquakes,
- volcanic eruptions,
- and the tide, also cause waves

If a breeze of less than 2 knots starts to blow across smooth water, small wavelets called ripples form almost instantaneously. When the breeze dies, the ripples disappear as suddenly as they formed, the level surface being restored by surface tension of the water.

If the wind speed exceeds 2 knots, more stable gravity waves gradually form, and progress with the wind. While the generating wind blows, the resulting waves may be referred to as sea. When the wind stops or changes direction, waves that continue on without relation to local winds are called swell.

Unlike wind and current, waves are not deflected appreciably by the rotation of the Earth, but move in the direction in which the generating wind blows. When this wind ceases, friction and spreading cause the waves to be reduced in height, or attenuated, as they move. However, the reduction takes place so slowly that swell often continues until it reaches some obstruction, such as a shore.

Chapter XXXII – Winds, waves, tides and cyclonic storms

3208. Tsunamis

A Tsunami is an ocean wave produced by sudden, large-scale motion of a portion of the ocean floor or the shore, such as a volcanic eruption, earthquake (sometimes called seaquake if it occurs at sea), or landslide. If they are caused by a submarine earthquake, they are usually called seismic sea waves. The point directly above the disturbance, at which the waves originate, is called the epicenter. Either a tsunami or a storm tide that overflows the land is popularly called a tidal wave, although it bears no relation to the tide.

If a volcanic eruption occurs below the surface of the sea, the escaping gases cause a quantity of water to be pushed upward in the shape of a dome. The same effect is caused by the sudden rising of a portion of the bottom. As this water settles back, it creates a wave which travels at high speed across the surface of the ocean.

In deep water the wave height of a tsunami is probably never greater than 2 or 3 feet. Since the wavelength is usually considerably more than 100 miles, the wave is not conspicuous at sea. In the Pacific, where most tsunamis occur, the wave period varies between about 15 and 60 minutes, and the speed in deep water is more than 400 knots. **The approximate speed can be computed by the formula: where S is the speed in knots, g is the acceleration due to gravity (32.2 feet per second per second), and d is the depth of water in feet.** This formula is applicable to any wave in water having a depth of less than half the wavelength. For most ocean waves it applies only in shallow water, because of the relatively short wavelength.

Chapter XXII – Calculations and Conversions

1 fathom _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ = 6 feet*

= 2 yards*

= 1.8288 meters*

1 cable_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ = 720 feet*

= 240 yards*

= 219.4560 meters*

1 cable (British) _ _ _ _ _ _ _ _ _ _ _ _ _ _ = 0.1 nautical mile

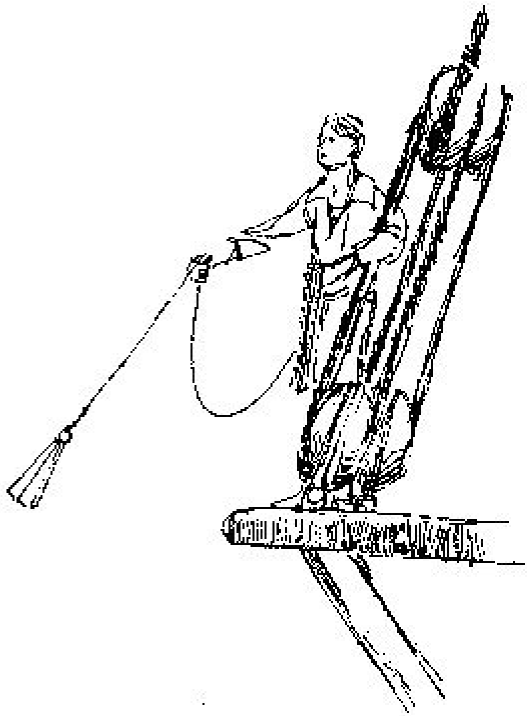
1 statute mile _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ = 5,280 feet*

= 1,760 yards*

= 1,609.344 meters*

= 1.609344 kilometers*

= 0.86897624 nautical mile



Sailor taking a fathom reading

Chapter XXII – Calculations and Conversions

1 nautical mile_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	= 6,076.11548556 feet
	= 2,025.37182852 yards
	= 1,852 meters*
	= 5 100*
	= 1.852 kilometers*
	= 1.150779448 statute miles
1 meter _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _	= 100 centimeters*
	= 39.370079 inches
	= 3.28083990 feet
	= 1.09361330 yards
	= 0.54680665 fathom
	= 0.00062137 statute mile
	= 0.00053996 nautical mile

Sailor taking a sextant reading

Chapter XVIII – Time in Navigation

TIME IN NAVIGATION

1800. Solar Time

The Earth’s rotation on its axis causes the Sun and other celestial bodies to appear to move across the sky from east to west each day. If a person located on the Earth’s equator measured the time interval between two successive transits overhead of a very distant star, he would be measuring the period of the Earth’s rotation. If he then made a similar measurement of the Sun, the resulting time would be about 4 minutes longer. This is due to the **Earth’s motion around the Sun, which continuously changes the apparent place of the Sun** among the stars. Thus, during the course of a day the Sun appears to move a little to the east among the stars, so that the Earth must rotate on its axis through more than 360° in order to bring the Sun overhead again

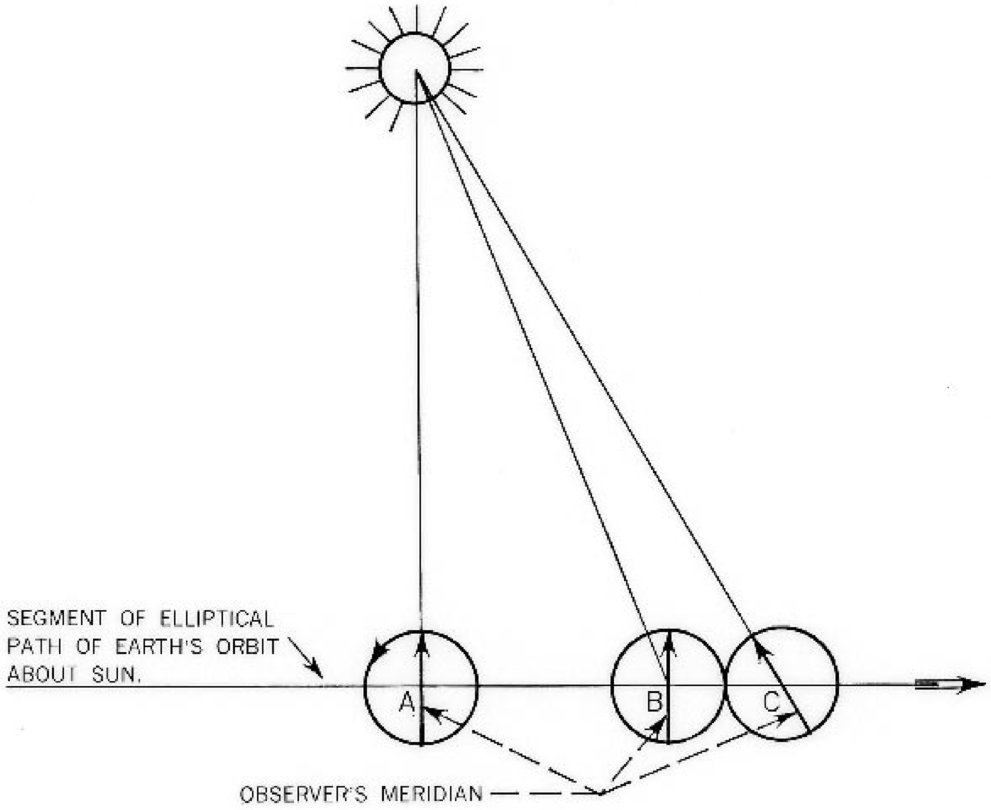


Figure 1800. Apparent eastward movement of the Sun with respect to the stars.

Chapter XVIII – Time in Navigation

Mean solar time, or mean time as it is commonly called, is sometimes ahead of and sometimes behind apparent solar time. **This difference, which never exceeds about 16.4 minutes, is called the equation of time**.

The navigator most often deals with the equation of time when determining the time of upper meridian passage of the Sun. The Sun transits the observer's upper meridian at local apparent noon. Were it not for the difference in rate between the mean and apparent Sun, the Sun would be on the observer's meridian when the mean Sun indicated 1200 local time. The apparent solar time of upper meridian passage, however, is offset from exactly 1200 mean solar time. This time difference, the equation of time at meridian transit, is listed on the right hand daily pages of the *Nautical Almanac*.

The sign of the equation of time is negative if the time of Sun's meridian passage is earlier than 1200 and positive if later than 1200.

Therefore: Apparent Time = Mean Time + (equation of time).

Chapter XVII – Azimuths and Amplitude Time in Navigation

1701. Compass Error by Azimuth of the Sun

Mariners may use *Pub 229, Sight Reduction Tables for Marine Navigation* to compute the Sun's azimuth. They **compare the computed azimuth to the azimuth measured with the compass** to determine compass error. In computing an azimuth, interpolate the tabular azimuth angle for the difference between the table arguments and the actual values of declination, latitude, and local hour angle. Do this triple interpolation of the azimuth angle as follows:

1. Enter the *Sight Reduction Tables* with the nearest integral values of declination, latitude, and local hour angle. For each of these arguments, extract a base azimuth angle.
2. Reenter the tables with the same latitude and LHA arguments but with the declination argument 1° greater or less than the base declination argument, depending upon whether the actual declination is greater or less than the base argument. **Record the difference between the respondent azimuth angle and the base azimuth angle** and label it as the azimuth angle difference (Z Diff.).

1701. Compass Error by Azimuth of the Sun

1. Reenter the tables with the base declination and LHA arguments, but with the latitude argument 1° greater or less than the base latitude argument, depending upon whether the actual (usually DR) latitude is greater or less than the base argument. Record the Z Diff. for the increment of latitude.
2. Reenter the tables with the base declination and latitude arguments, but with the LHA argument 1° greater or less than the base LHA argument, depending upon whether the actual LHA is greater or less than the base argument. Record the Z Diff. for the increment of LHA.
3. **Correct the base azimuth angle for each increment**.

	Actual	Base Arguments	Base Z	Tab* Z	Z Diff.	Increments	Correction (Z Diff x Inc.÷ 60)
Dec.	20°13.8' N	20°	97.8°	96.4°	–1.4°	13.8'	–0.3°
DR Lat.	33°24.0' N	33°(Same)	97.8°	98.9°	+1.1°	24.0'	+0.4°
LHA	316°41.2'	317°	97.8°	97.1°	– 0.7°	18.8'	–0.2°

Base Z	97.8°
Corr.	(–) 0.1°
Z	N 97.7° E
Zn	097.7°
Zn pgc	096.5°
Gyro Error	1.2° E

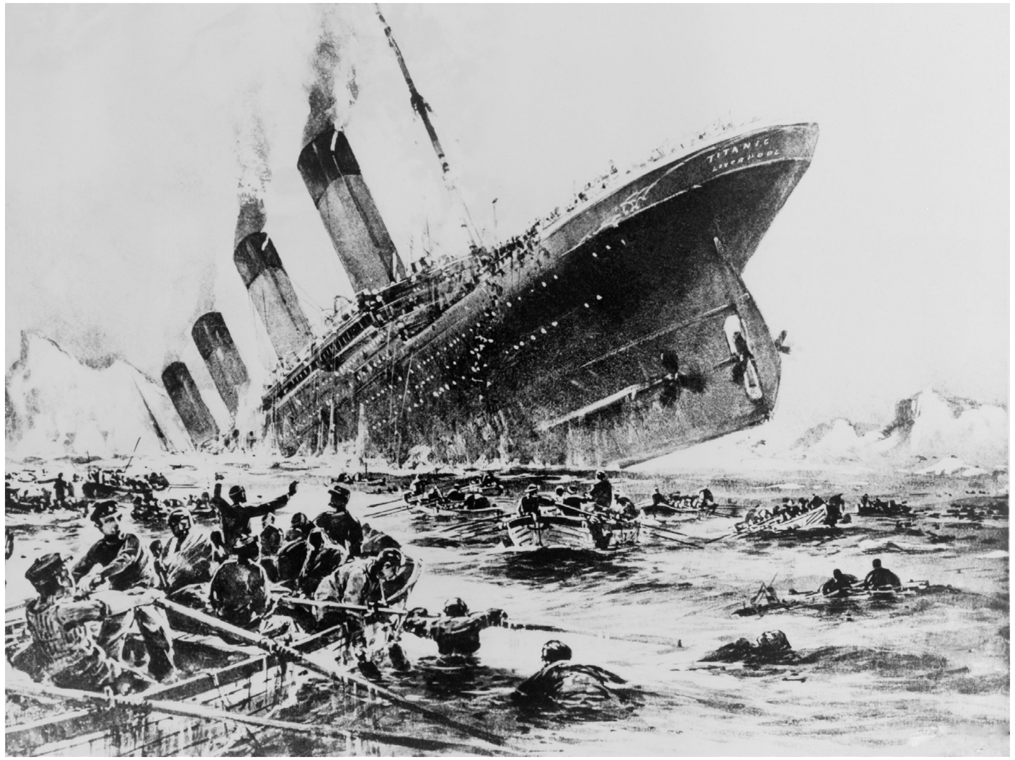
Total Corr.	–0.1°

*Respondent for the two base arguments and 1° change from third base argument, in vertical order of Dec., DR Lat., and LHA.

Chapter XXXIII – Ice Navigation

3313. Operations in Ice

Ice conditions may change rapidly while a vessel is working in pack ice, necessitating quick maneuvering. Conventional vessels, even if ice strengthened, are not built for ice breaking. The vessel should be conned to first attempt to place it in leads or polynyas, giving due consideration to wind conditions. The age, thickness, and size of ice which can be navigated depends upon the type, size, hull strength, and horsepower of the vessel employed. If contact with an ice floe is unavoidable, **never strike it a glancing blow.** This maneuver may cause the ship to veer off in a direction which will swing the stern into the ice. **If possible, seek weak spots in the floe and hit it head-on at slow speed.**

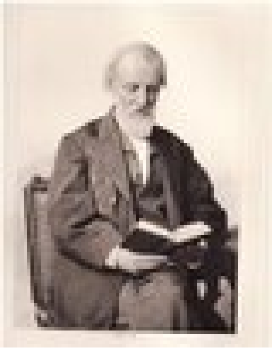


15 April 1912, the Sinking of the *RMS Titanic*

Nathaniel Bowditch - family

Mary Hodges Ingersoll
1781 - 1834

Children	Born - Died
Nathaniel Ingersoll Bowditch	1805 - 1861
Jonathon Ingersoll Bowditch	1806 - 1889
Henry Ingersoll Bowditch	1808 - 1892
Charles Ingersoll Bowditch	1809 - 1820
Mary Ingersoll Bowditch Dixwell	1816 - 1893
William Ingersoll Bowditch	1819 - 1909
Elizabeth Boardman Ingersoll Bowditch Dixwell	1823 - 1888



Henry Bowditch

In March 1798 while Bowditch was back in Salem between voyages, he married Elizabeth Boardman but sadly she died seven months after the wedding. In 1800, before he made his last voyage, Bowditch married for the second time. His **second marriage was to Mary Ingersoll who was a cousin**.

Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

Nathaniel Bowditch – home and business

Bowditch was now coming up in the world and he gave up his career as a sailor in 1804 to move into the business world. In that year he became **president of the Essex Fire and Marine Insurance Company** in Salem and under his leadership the Company prospered despite difficult conditions due to the war of 1812 and other political problems. During the years of his presidency of this Company **Bowditch undertook mathematical and astronomical investigations which gave him a high reputation in the academic world.**

Nathaniel & Mary Bowditch House

Essex Street – early 1800s

*Nathaniel Bowditch and the Power of Numbers***,** Tamara Plakins Thornton, The University of North Carolina Press, Chapel Hill, 2016

Nathaniel Bowditch – home and business

First Five Presidents of the American Academy of Science	
James Bowdoin	1780 - 1790
John Adams	1791 - 1814
Edward Augustus Holyoke	1814 - 1820
John Quincy Adams	1820 - 1829
Nathaniel Bowditch	1829 - 1838

Salem, Massachusetts, early 1800s

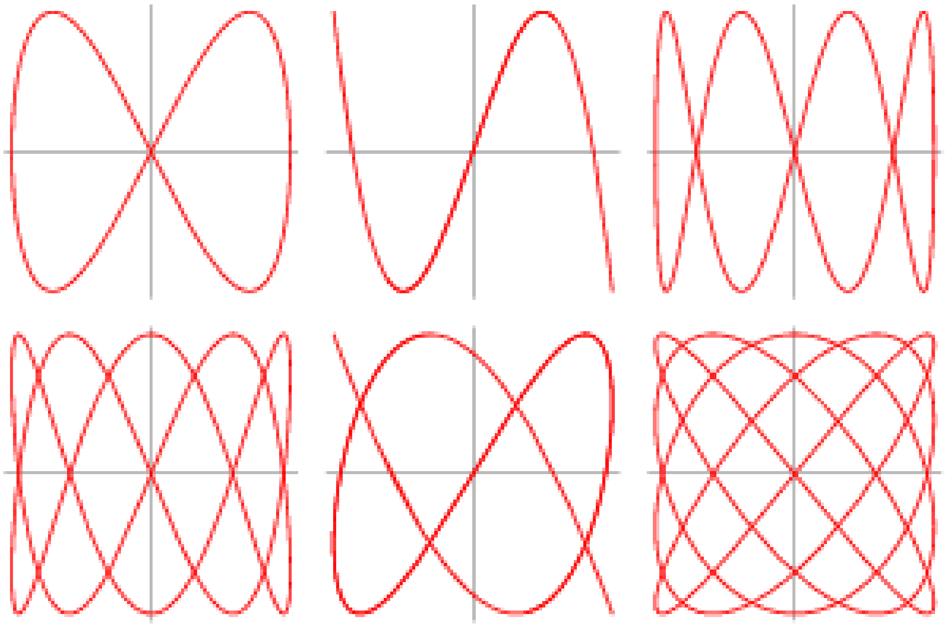
Bowditch had already received high recognition for his academic contributions, including election to the American Academy of Sciences in 1799. He was offered the chair of mathematics and physics at Harvard in 1806 but he turned it down. In 1804 he had published an article on observations of the moon, and in 1806 he published naval charts of the harbour at Salem and several other harbours.

Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

Nathaniel Bowditch – home and business

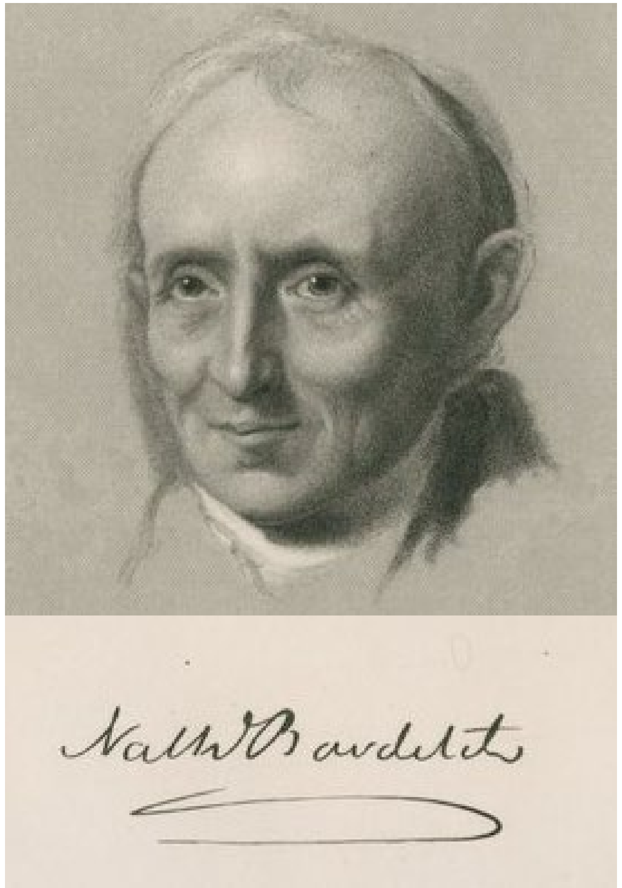
More scientific publications followed such as:

- one on a meteor explosion in 1807
- three papers on orbits of comets (1815, 1818, 1820)
- and in 1815 he studied **Lissajous figures while studying the motion of a pendulum suspended from two points**



Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

Nathaniel Bowditch – home and business



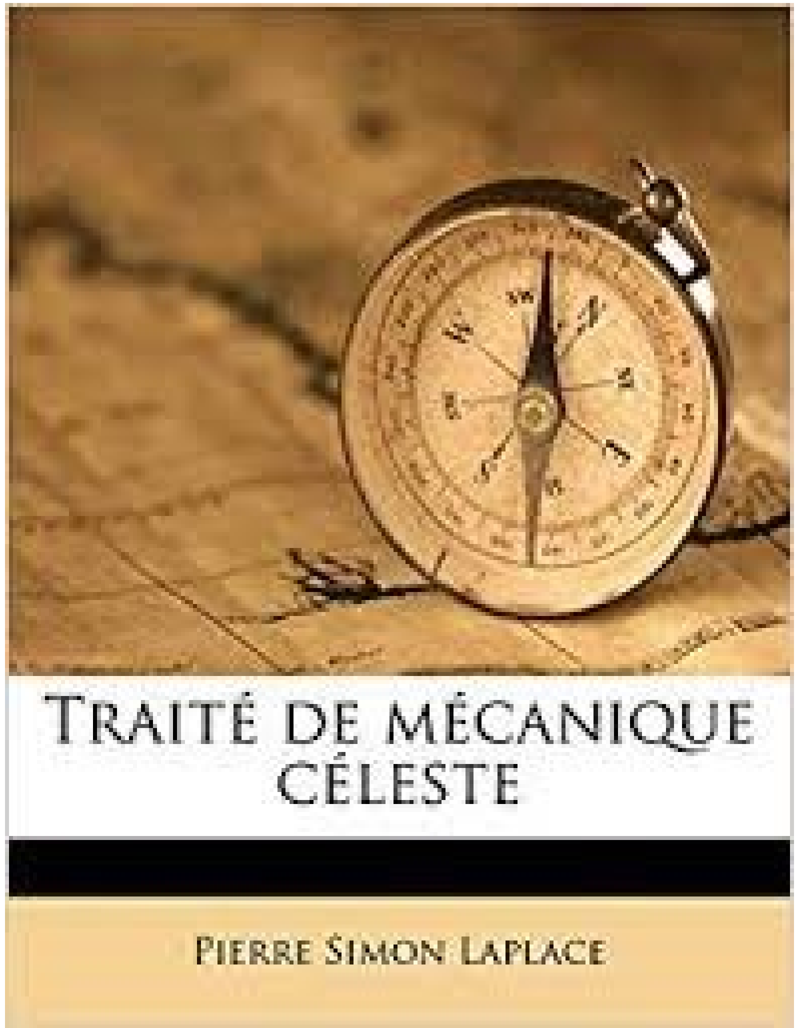
Harvard University was not the only one to offer Bowditch a chair. He was also offered one by West Point and, in 1818, he was offered the chair at the University of Virginia.

*Nathaniel Bowditch and the Power of Numbers***,** Tamara Plakins Thornton, The University of North Carolina Press, Chapel Hill, 2016

Nathaniel Bowditch – home and business

When Bowditch moved from Salem to Boston in 1823, **he moved 2,500 books, more than 100 maps and charts and 29 volumes of his own manuscripts**. As president of the Massachusetts Hospital Life Insurance Company, he enjoyed enough material success so that he could afford the $12,000 it cost to have his translation of Laplace published (1829-1839).

> Bowditch's translation of the first four volumes of Laplace's *Traité de mécanique céleste* was completed by 1818 but he would not publish it for many years … Bowditch was helped by Benjamin Peirce in this project and his commentaries doubled the length of the book. His purpose was more than just an English translation. He wanted:
>
> *… to supply steps omitted in the original text; to incorporate later results into the translation; and to give credits omitted by Laplace*



Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

By this time Bowditch had a high international reputation for he had published articles in Great Britain and Europe as well as America.

He was elected to the:

- American Philosophical Society in 1809
- Royal Society of Edinburgh in 1818
- Royal Society of London in 1818
- Royal Irish Academy in 1819

RIA
ROYAL IRISH ACADEMY

RSE
The Royal Society of Edinburgh
KNOWLEDGE MADE USEFUL

Royal Society of London

Joseph Albree, *Salem's Bowditch*, The Mathematical Intelligencer, 1992

America's Cup – 22 August 1851

***America* was commissioned by a syndicate** headed by Commodore John Cox Stevens of the New York Yacht Club **specifically to take up a challenge** proffered by Lord Wilton, of Grosvenor Square, London, commodore of the Royal Yacht Squadron, in a letter dated 22 February, 1851, the year of the Great Exhibition.

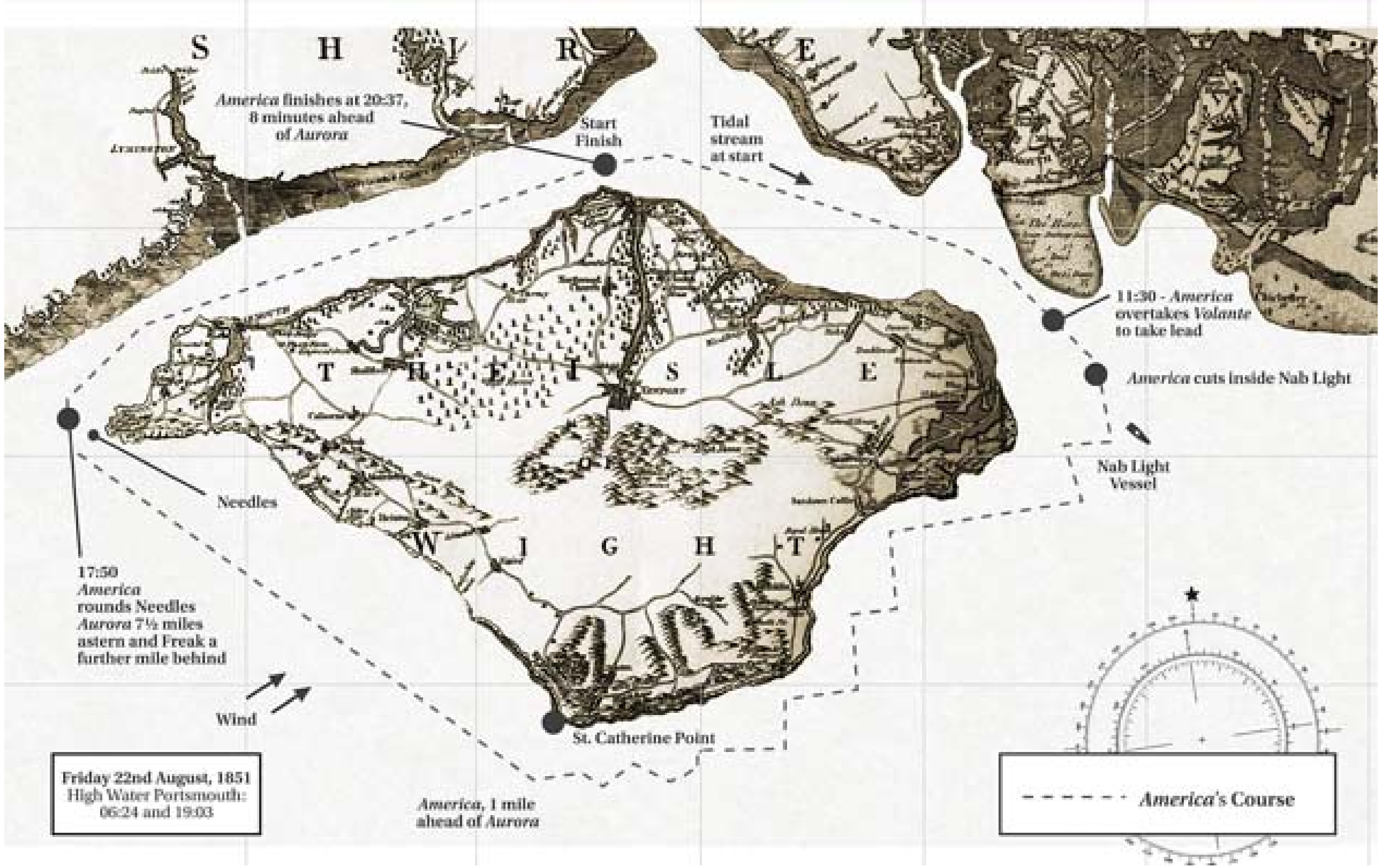
The price agreed for her building was high – $30,000 – but extraordinary conditions were written into the contract. If she did not prove to be the fastest vessel in the United States the syndicate could refuse her.

She was a gamble even on the drawing board, her underwater shape influenced by Englishman John Scott Russell's Wave Line theory, which aimed to produce a hull that offered least resistance to the water, concave bows replacing the rounded bows of the era.

Yachting World, 15 January 2017

America's Cup – 22 August 1851

The Royal Yacht Squadron, stung by the criticism in the press, finally took the plunge. The race, 53 miles around the Isle of Wight, was scheduled for 22 August and **the prize was to be a 27-inch cup made of 134 ounces of silver**, worth £100 paid for by the membership.



Yachting World, 15 January 2017

America’s Cup – 22 August 1851

Queen Victoria on board the schooner *America*

left to right: Colonel James A. Hamilton
Lord Alfred Paget, the Queen’s clerk marshal
Prince Albert, the Prince Consort
the Queen, Commodore John C. Stevens

From an oil painting by C. Chase Emerson

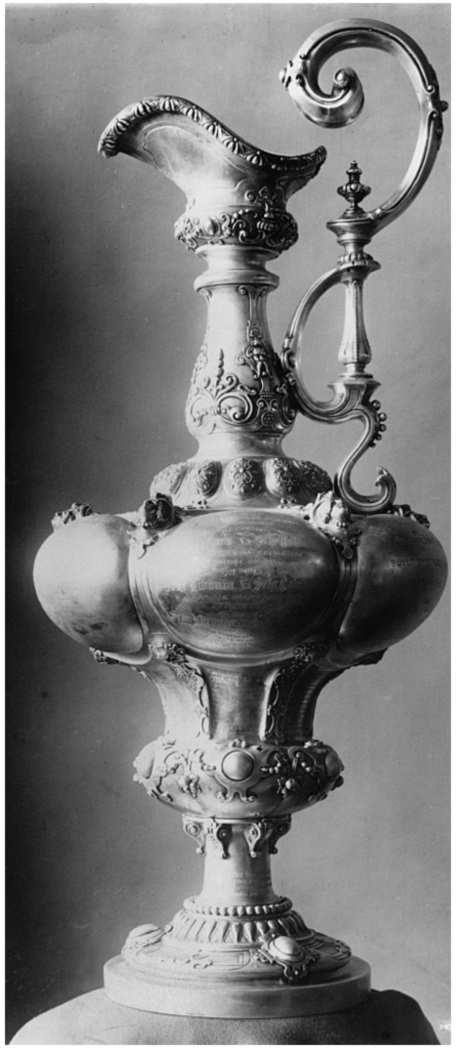
In 1983, the United States lost the trophy for the first time in 132 years
when Australia II defeated Liberty off Newport, Rhode Island.

Yachting World, 15 January 2017

America's Cup

Year(s)	Country
1851 - 1983	United States
1987	Australia
1988 - 1995	United States
2000 - 2003	New Zealand
2007 - 2010	Switzerland
2013 - 2016	United States
2017	New Zealand

Yacht Club	Country	Won - Loss	% Won - Loss
New York Yacht Club	United States	25 - 1	96%
San Diego Yacht Club	United States	3 - 1	75%
Société Nautique de Genève	Switzerland	2 - 1	67%
Golden Gate Yacht Club	United States	2 - 1	67%
Royal New Zealand Yacht Squadron	New Zealand	3 - 3	50%
Royal Perth Yacht Club	Australia	1 - 3	25%



The America's Cup
aka Auld Mug

First Battle of Ironclads – 8 & 9 March 1862

USS Monitor and CSS Virginia
Hampton Roads

On 8 March 1862 at Hampton Roads where the Elizabeth and Nansemond rivers meet before they flow into the Chesapeake Bay, the **CSS V*irginia* destroyed two ships of the *USS Congress* and the *USS Cumberland*** and was about to attack the *USS Minnesota* when halted by darkness and a falling tide

During the night, however, the ironclad *USS Monitor* had arrived and had taken a position to defend the *Minnesota*. When *Virginia* approached, *Monitor* intercepted her. The two ironclads fought for about three hours, with neither being able to inflict significant damage on the other. The duel ended indecisively, *Virginia* returning to her home at the Gosport Navy Yard for repairs and strengthening, and *Monitor* to her station defending *Minnesota*. **The ships did not fight again**, the blockade remained.

The South built 21 iron clads, the North 58.

Official Records of the Union and Confederate Navies in the War of the Rebellion, 1894 - 1922

Battle of Hampton Roads 8 - 9 March 1862

USS Monitor

THE TIMES

When the news of the Monitor-Virginia duel reached England, the London Times commented: “Whereas we had available for immediate purposes one hundred and forty-nine first-class warships, **we now have two**, these two being the Warrior and her sister Ironside.

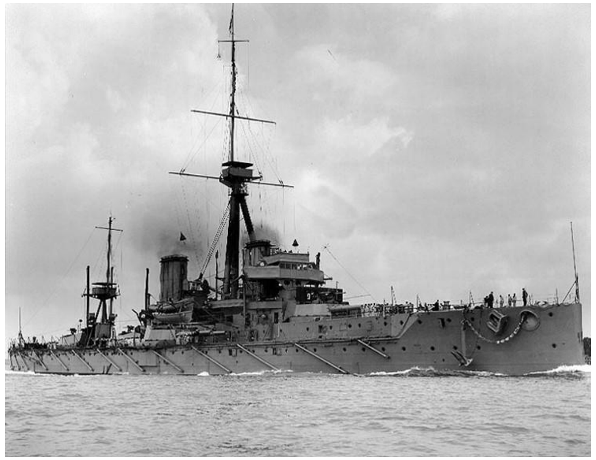
There is not now a ship in the English navy apart from these two that it would not be madness to trust to an engagement with that little Monitor.

John Taylor Wood, *The First Fight of Iron-Clads,* Century Company, New York, 1887

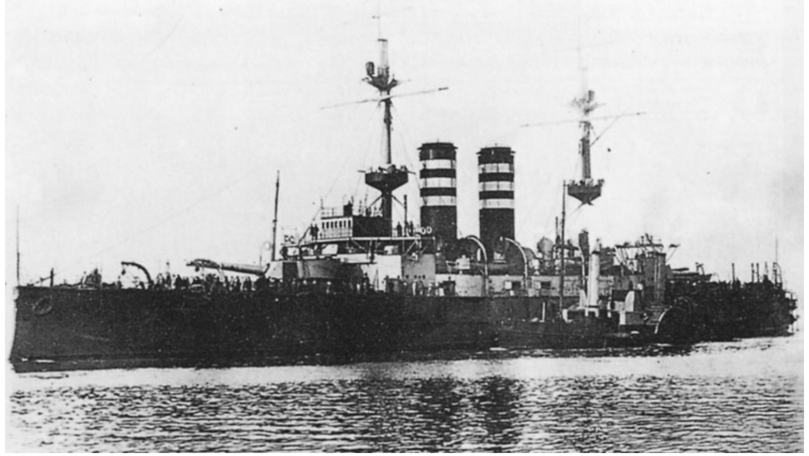
Early 20th Century Iron Ships

In the last third of the nineteenth century the world's navies converted to iron and steel, **incorporating the principal features of John Ericsson's folly:**

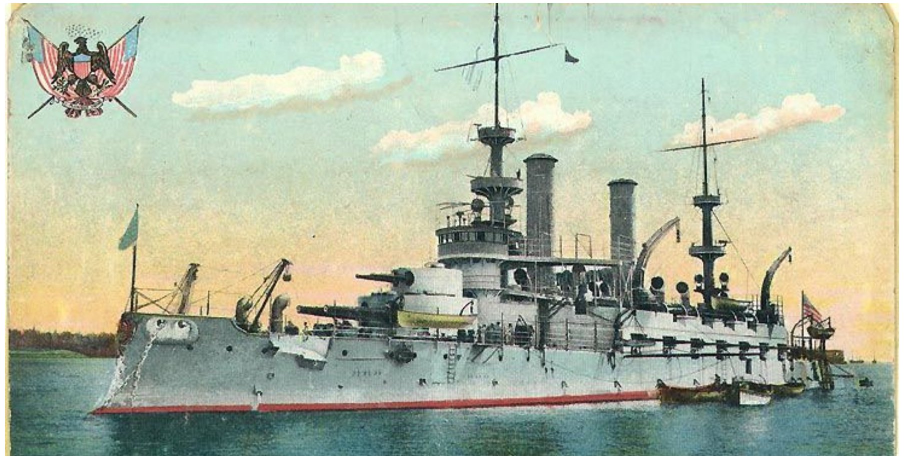
- Low profiles
- Speed and maneuverability
- Revolving gun turrets
- A few guns of heavy caliber rather than multiple broadsides



HMS Dreadnaught – Great Britain



HJMS Aki - Japan



USS Kearsarge – United States

James M. McPherson, Battle Cry of Freedom, Oxford University Press, 2003

Statutes of Authorization – Revised Statute 431, 21 June 1866

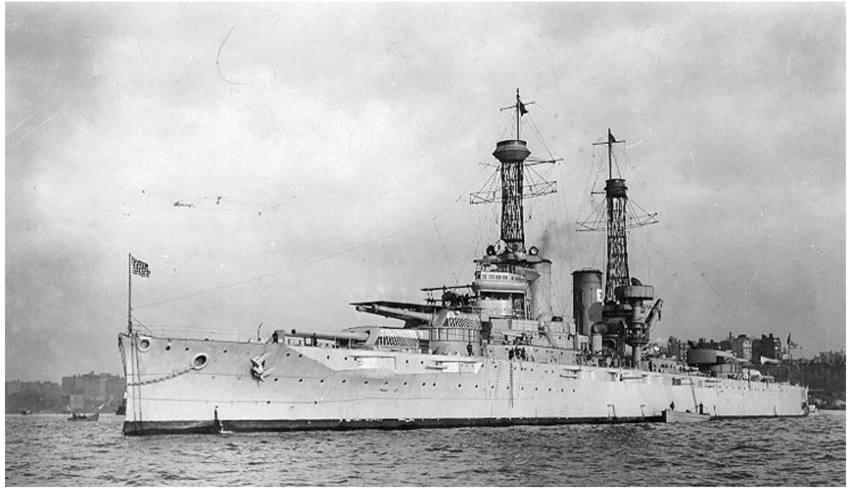
There shall be a Hydrographic Office attached to the Bureau of Navigation in the Navy Department, for the improvement of the means for navigating safely the vessels of the Navy and of the mercantile marine, by providing, under the authority of the Secretary of the Navy, accurate and cheap nautical charts, sailing directions and manuals of instructions for the use of all vessels of the United States and for the benefit and use of navigators generally.

USS President - 1800

Statutes of Authorization – Revised Statute 432

The Secretary of the Navy is authorized to cause to be prepared, at the Hydrographic Office attached to the Bureau of Navigation in the Navy Department, maps, charts and nautical books relating to and required in navigation and to publish and furnish them to navigators at the cost of printin and paper and to purchase the plates and copyrights of such existing maps, charts, navigators, sailing directions and instructions as he may consider necessary and when he may deem it expedient to do so and under such regulations and instructions as he may prescribe.

US Navy next generation frigate, scheduled launch 2026



USS Texas

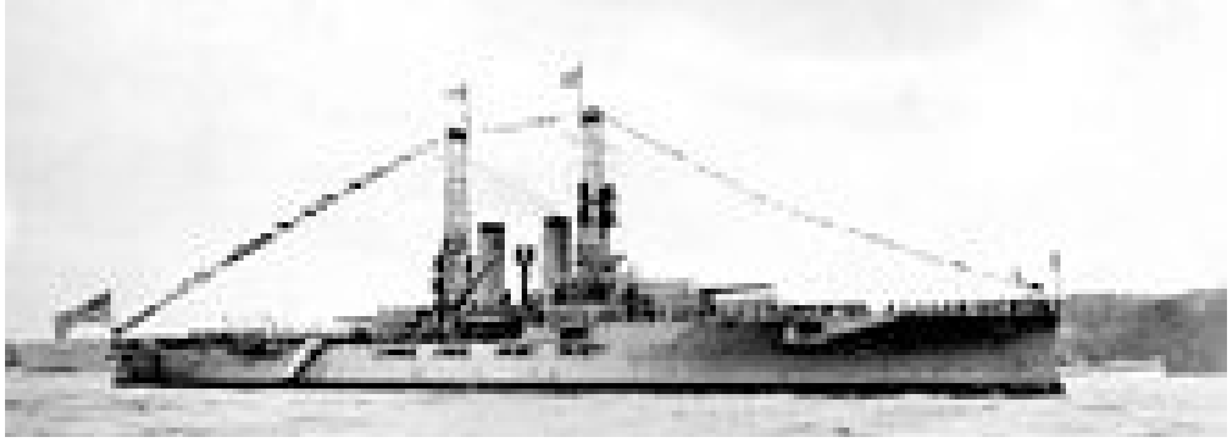
Charles Race

Major Naval Power Strength 1914

	Great Britain	Germany	United States	Japan	France
Battleships	22	15	10	2	2
Battle Cruisers	9	5		1	
Cruisers	87	33	34	27	28
TOTAL	118	53	44	30	30

Charles Race, *The Rise of the American Navy 1775 - 1914*, History.net

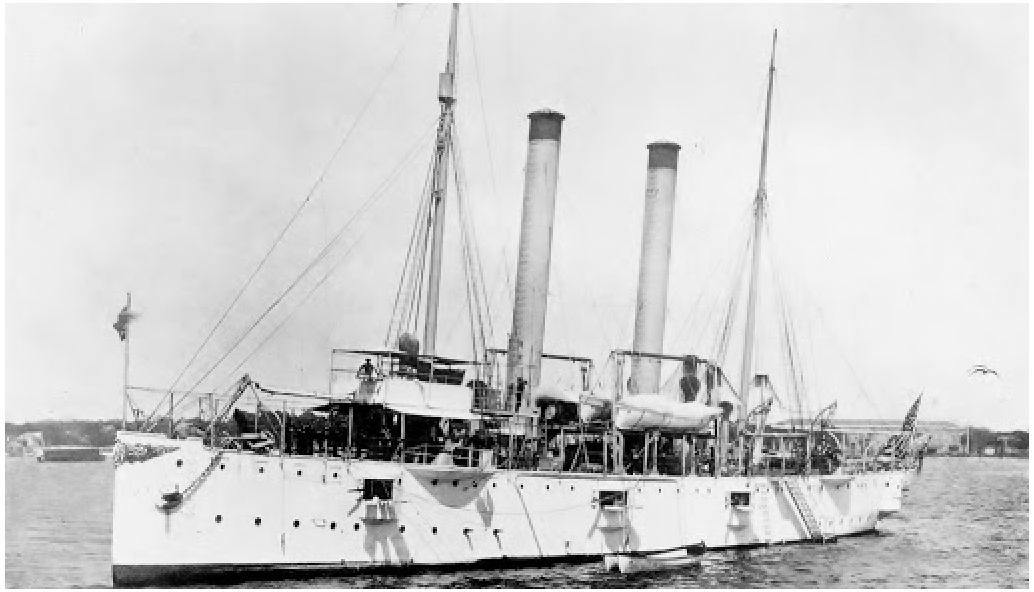
Battleship - USS Delaware (BB-28)



Battleship - USS Florida (BB-30)

US Navy and Its Rise to Global Parity

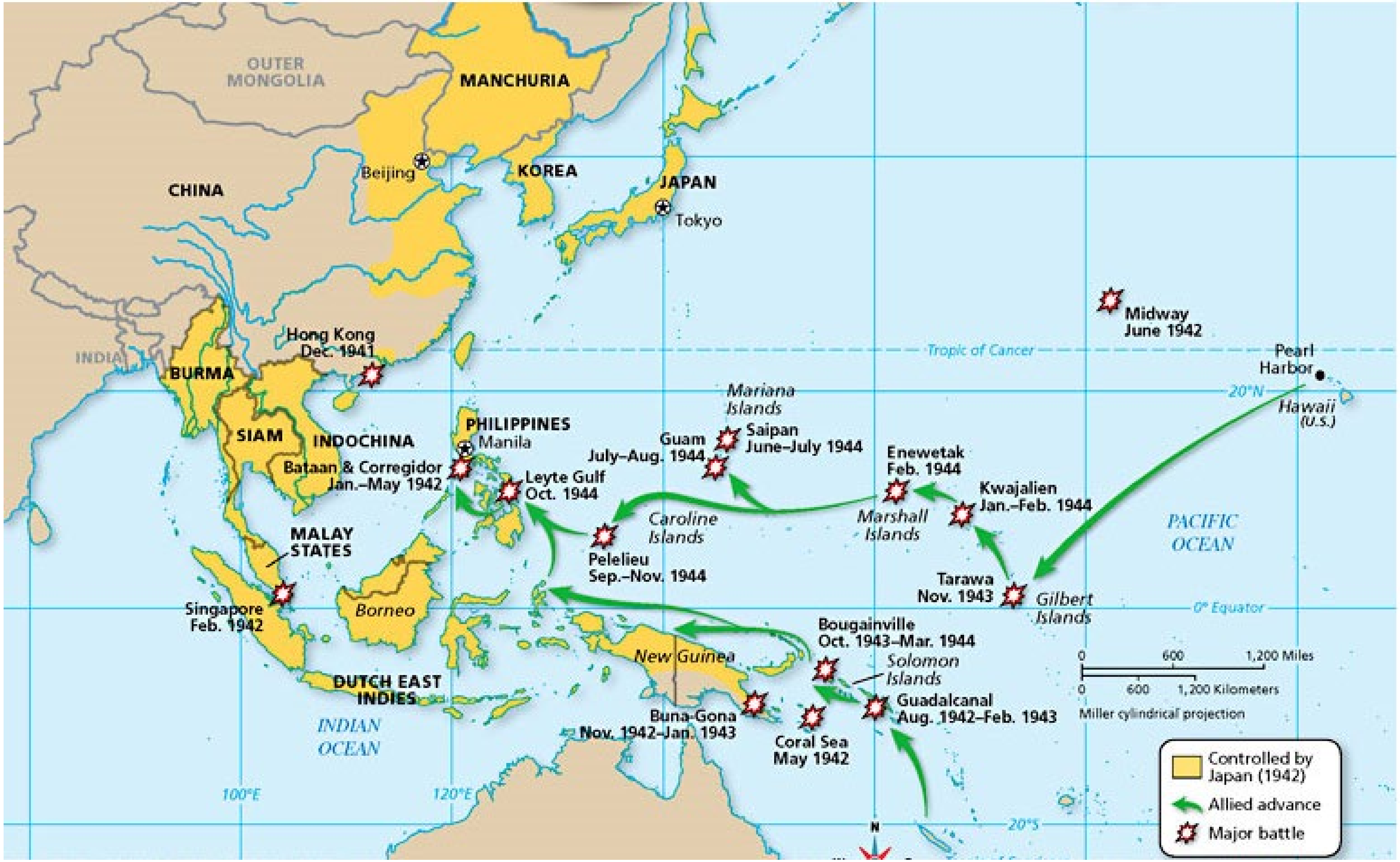
Destroyer – USS Bainbridge (DD-1)



Gunboat – USS Nashville (PG-1)

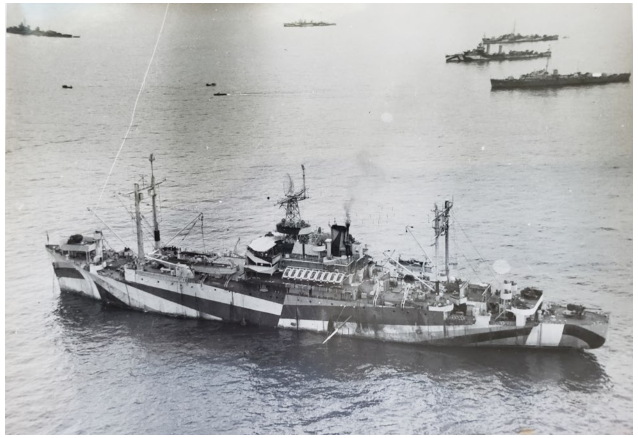
US Navy and Its Rise to Global Parity

US Navy in World War II



USS Wasatch (AGC-9)

Log of Movements
19 September through 29 October 1944
Aram L. Ehramjian Chief Radio Electrician
Assistant Radio Materiel Officer, USS Wasatch, 315964 USNR



Log of Movements	Date
Arrived Hollandia, Dutch New Guinea at 1700	19 September
Left Hollandia at 0830 for Leyte invasion	15 October
Arrived Leyte Gulf, Philippine Islands at 1600 **Invasion:** Wasatch was the flagship of the 7th fleet (Admiral Kinkaid). General McArthur returns to the Philippines aboard the USS Nashville.	20 October
The Battle of Leyte Gulf, the largest naval battle of all time. Admiral Kinkaid, aboard the Wasatch, commanded the naval forces of the 7th fleet. The 7th fleet was extremely successful during this battle.	25 October
Left Leyte Gulf (off Tacloban) at 1600 Ran into a very bad typhoon	29 October

The Battle of Leyte Gulf

19 September to 29 October 1944

Battle	United States & Australia	Japan
1. Sibuyan Sea	Frederick Sherman task group 38.3	Takeo Kurita center force
2. Surigao Straight	Jesse B. Oldendorf task group 77.2	Shōji Nishimura southern force
3. Cape Engaño	Willis Lee task force 34	Jisaburō Ozawa northern force
4. Samar	Clifton Sprague task unit 77.4.3 (Taffy 3)	Takeo Kurita center force

General Douglas MacArthur had just landed on the beaches of the Philippine Island of Leyte when the Japanese Navy attacked. In the Battle of Leyte Gulf, 10,000 Japanese and 3,000 Americans sailors died.

US Navy Today

The Navy indicates that the next-generation attack submarine should be faster, stealthier, and able to carry more torpedoes than the Virginia class (at $5.4B) —**similar to the Seawolf-class submarine**. CBO therefore assumed that the SSN(X) would be a Seawolf-sized SSN, which displaces about 9,100 tons when submerged, and would have an all-new design in keeping with the Navy's description of it as a '**fast, lethal next-generation attack submarine**'

USN Seawolf (SSN-21)

Megan Eckstein, US Naval Institute, 10 October 2019

Most Virginia-class boats procured in FY2019 and subsequent years are to be built with **the Virginia Payload Module (VPM)**, an additional, 84-foot-long, mid-body section equipped with four large-diameter, vertical launch tubes for storing and launching additional Tomahawk missiles or other payloads.

Virginia-class submarine USN Missouri

"There are two types of ships, submarines and targets" - Tom Clancy

Megan Eckstein, US Naval Institute, 10 October 2019

US Navy Today

		Total Costs per Class over the 2020-2049 Period		Average Cost per Ship under the 2020-2049 Plan	
Type of Ship	Number of New Ships Purchased under the 2020 Plan	Navy Estimate	CBO Estimate	Navy Estimate	CBO Estimate
CVN-78 Gerald R. Ford class aircraft carriers	7	87	91	12.7	13.0
SSBN-826 Columbia class ballistic missile submarines	12	82	90	7.2	7.9
Large payload submarines	5	34	37	7.1	7.8
SSN-774 Virginia class attack submarines with VPM	28	83	87	2.8	2.9
SSN(X) future attack submarines	33	112	181	3.4	5.5
DDG-51 Flight III Arleigh Burke class destroyers	15	26	27	1.7	1.8
Future large surface combatants	61	102	169	1.7	2.8

Congressional Budget Office (CBO) using Navy data - $ billions, excluding R&D

Nathaniel Bowditch (1773 – 1838)

Death at 65 on 16 March 1838, closed a record of wonderful achievement during a life of stainless integrity. Many honors had been conferred upon him by his fellow men. The following eulogy was written by the **Salem Marine Society**.

> **In his death a public, a national, a human benefactor has departed.** Not this community nor our country only, but the whole world has reason to do honor to his memory. When the voice of eulogy shall be still, when the tears of sorrow shall cease to flow, no monument will be needed to keep alive his memory among men; but as long as ships shall sail, the needle point to the north and the stars go through their wanted courses in the heavens, the name of **Dr. Bowditch will be revered as of one** who has helped his fellow countrymen in time of need, **who was and is a guide to them over the pathless oceans and one who forwarded the great interests of mankind.**

US Navy Hydrographic Office

For Further Reading

- ***American Sailing Ships*** by Charles G. Davis, Dover Publications Inc., New York, 2019

- ***Nathaniel Bowditch and the Power of Numbers*** by Tamara Plakins Thornton, The University of North Carolina press, Chapel Hill, 2016

- ***Time and Navigation*** by Andrew K. Johnson, Roger D. Connor, Carlene E. Stephens, Paul E. Ceruzzi, Smithsonian Books, Washington, 2015

- ***The History of Ships*** by Peter Kemp, Galahad Books, New York, 1978

- ***American Practical Navigator*** by Nathaniel Bowditch first published in 1802, Revised edition of 1938, United States Government Printing Office, Washington, 1939