Navigation at the dawn of history

- In the early days, sailors followed the coast to avoid getting lost on the high seas
- When the first navigators sailed towards the ocean, they discovered they could keep track of their route by following the stars
- As stars look different from different points on Earth, by observing the heavens seamen could obtain indications on the direction to take
- Observing the stars was the main navigation method for centuries
- Unfortunately, though, stars are visible only at night (and only with good weather).

Navigation in Homer's Odyssey

- **In Homer's poem, Ulysses (Odysseus), navigating to Ithaca from Ogygia, Calypso's island, kept the Great Bear constellation (Ursa Major) on his left side, as the goddess Athena had suggested to him.**

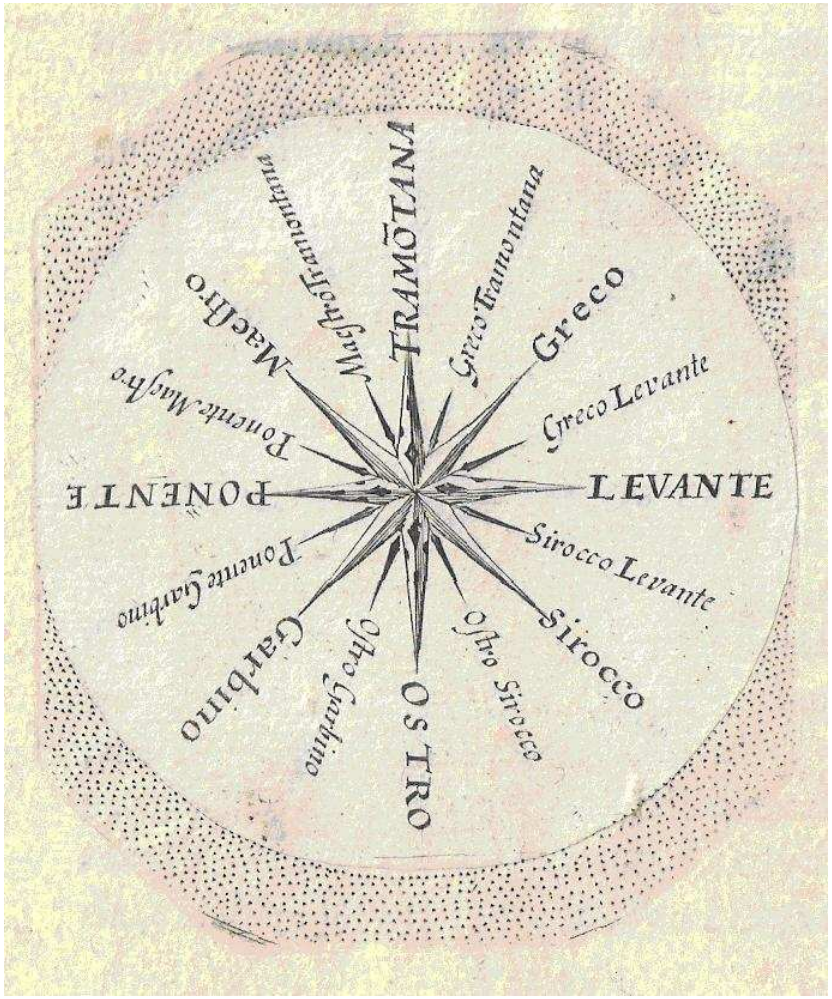
The first technological breakthrough: the magnetic compass (1/2)

The first technological breakthrough: the magnetic compass (2/2)

- **In a compass the needle always points north (the "magnetic" north, to be precise), indicating the direction of movement at any time of the day and whatever the weather**
- **The origins of the compass are mysterious and uncertain: some argue it was invented by the Chinese, while others maintain it is the invention of the Arabs, the Norsemen or of seamen from Amalfi**
- **In any case, this instrument almost certainly made its appearance in Europe around the year one thousand, taking on its definitive shape in 1300 (probably) at the hands of the legendary Flavio Gioia from Amalfi.**

Compass: a Chinese invention?

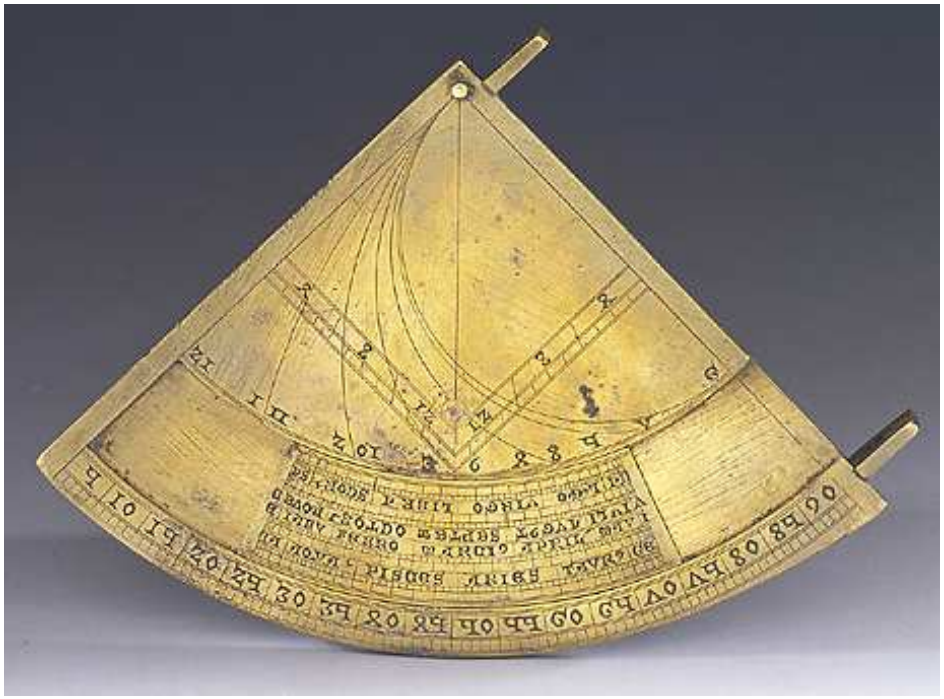
“Prima dedit nautis usum magnetis Amalphis”



Cristoforo Colombo, a genius in navigation

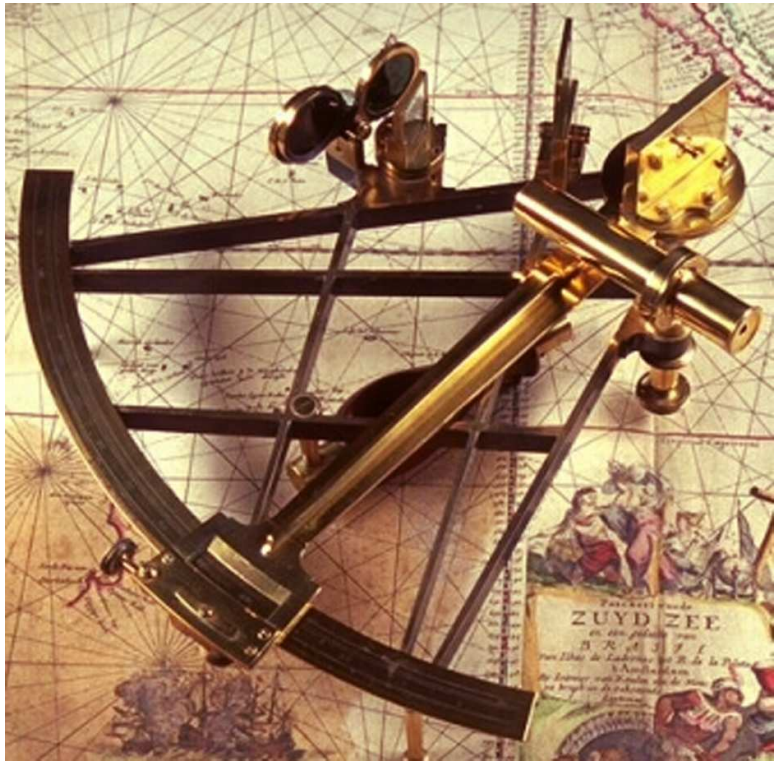
Compass, log, observation of the stars and sun, knowledge of currents and winds, and a meticulous care in the compilation of the logbook were for many centuries the basis of the "estimated navigation" ("dead reckoning"). A brilliant user of this technique, as it is clear from reading the chronicles of his journeys, was Cristoforo Colombo.

The history of the sextant: kamal, astrolabe, quadrant



Matteo Ricci, S. J.: an Italian astronomer in 16th century Ming's China

The sextant

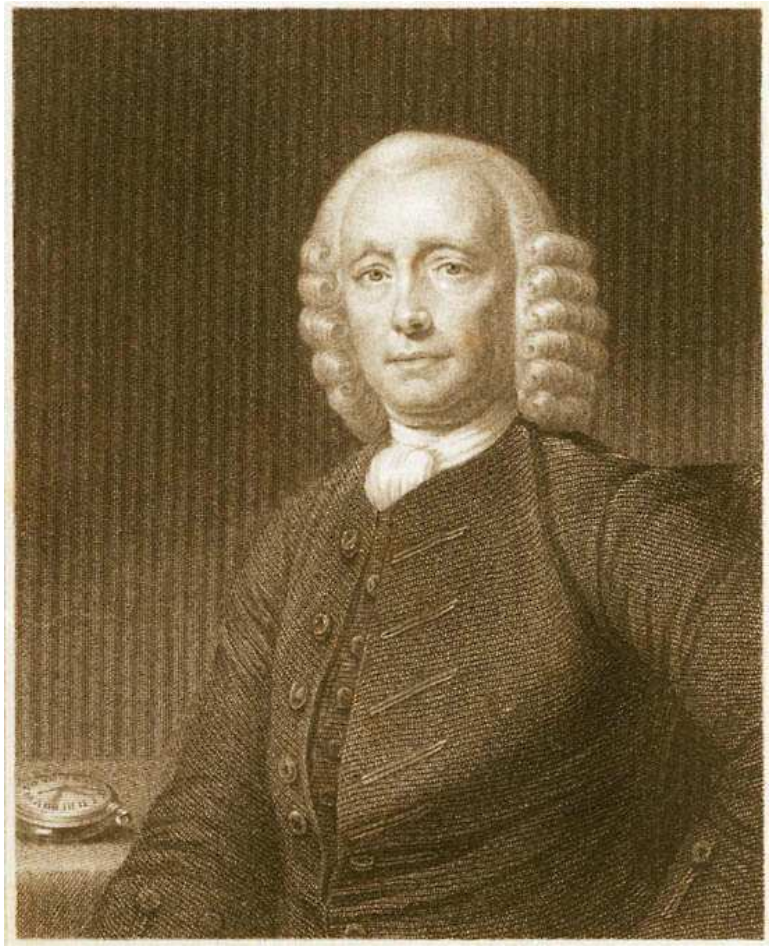


- The sextant, invented in 1732, uses a system of mirrors to measure the exact angle of stars, the moon and the sun above the horizon
- Initially, however, the sextant could only determine latitudes (i.e. the position on Earth measured north or south of the equator)
- Seamen were still unable to calculate their longitude (i.e. the position on Earth east or west of a reference meridian).

The “Longitude Problem”

- **For more than two centuries the issue of longitude determination on the high seas enticed the most enlightened minds in Europe and became such a major concern that in 1713 Britain, with the “Longitude Act”, formed a group of famous scientists (the “Longitude Board”) to find a possible solution**
- **The group offered twenty thousand pounds, equivalent to one million dollars today, to anyone who proved to be able to determine the longitude of a ship in open water with an accuracy of thirty nautical miles (about 55 kilometers)**
- **The initiative was successful. In 1761, a self-taught artisan, John Harrison, built a special mechanical clock to take onboard ships, the marine chronometer, which lost or gained no more than one second a day.**

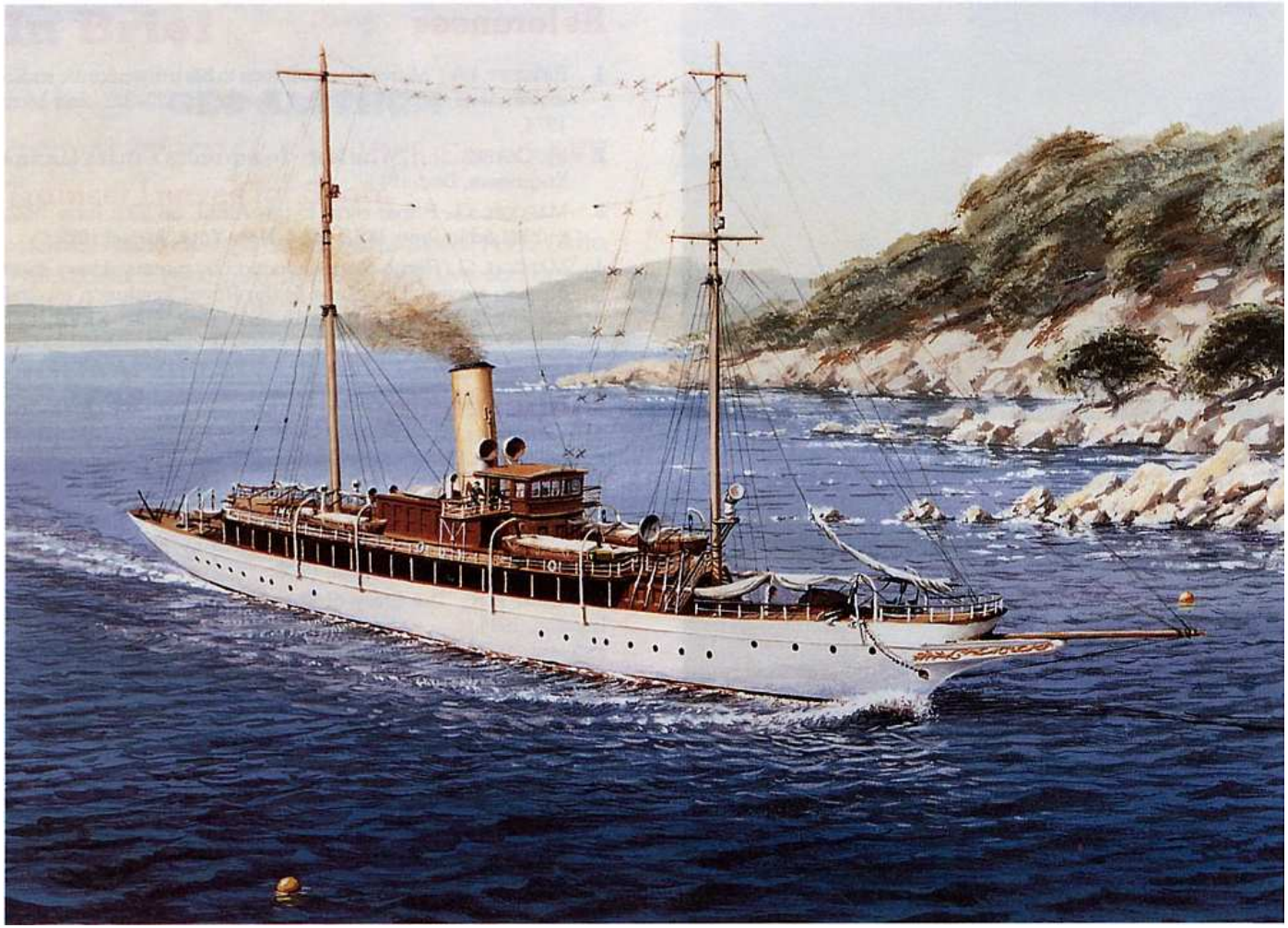
John Harrison and his “jewels”



Navigation in the XVIII and XIX centuries

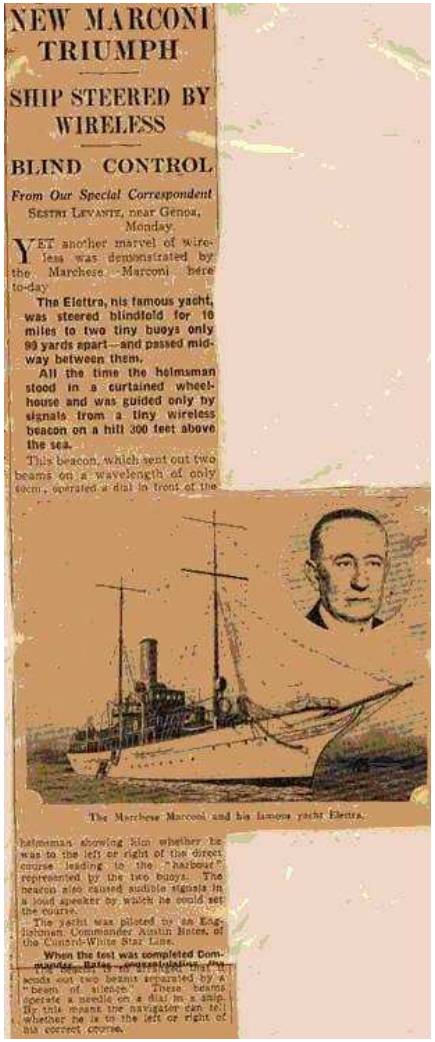
- Over the XVIII and XIX centuries, sextants and chronometers were used in combination to obtain information on latitude and longitude
- However, one should bear in mind that, especially during long sea voyages, accumulating minutes of error in determining the time was easy; a chronometer with an error of 4 minutes leads to a one degree error in longitude (equivalent to more than one hundred kilometers at the equator)
- It was only at the beginning of the twentieth century that, with the advent of radio waves, various radio navigation systems were developed, which were then widely used during the Second World War
- The principle of radio navigation ("Radio Direction Finder", RDF), based on the use of a radio source to guide the navigation of a mobile means (airplane or ship) through the use of a directional antenna, was invented by the Marconi Company in the early 1900s. In 1931, the system was so widespread that it became mandatory on all vessels with a tonnage of 5,000 tons or more.

30th July 1934, Sestri Levante: Marconi's blind control



“New Marconi triumph: Ship steered by wireless – Blind control”

- **On 31st July 1934, an article in the British Daily Mail described the success of the experiments carried out by Marconi at Sestri Levante, onboard his yacht-laboratory Elettra.**
- **It explained how Marconi, in the presence of technicians, Italian and British Navy officials and numerous representatives of the press, had used a beacon operating on the 60 centimeters wavelength (500 MHz), installed along the coast at a height of 100 meters above sea level, to direct the navigation of the boat through a route marked out by buoys.**



NEW MARCONI TRIUMPH

SHIP STEERED BY WIRELESS

BLIND CONTROL

From Our Special Correspondent

SESTRI LEVANTE, near Genoa, Monday

YET another marvel of wireless was demonstrated by the Marchese Marconi here to-day.

The Elettra, his famous yacht, was steered blindfold for 10 miles to two tiny buoys only 99 yards apart—and passed midway between them.

All the time the helmsman stood in a curtained wheelhouse and was guided only by signals from a tiny wireless beacon on a hill 300 feet above the sea.

This beacon, which sent out two beams on a wavelength of only 60cm., operated a dial in front of the

The Marchese Marconi and his famous yacht Elettra.

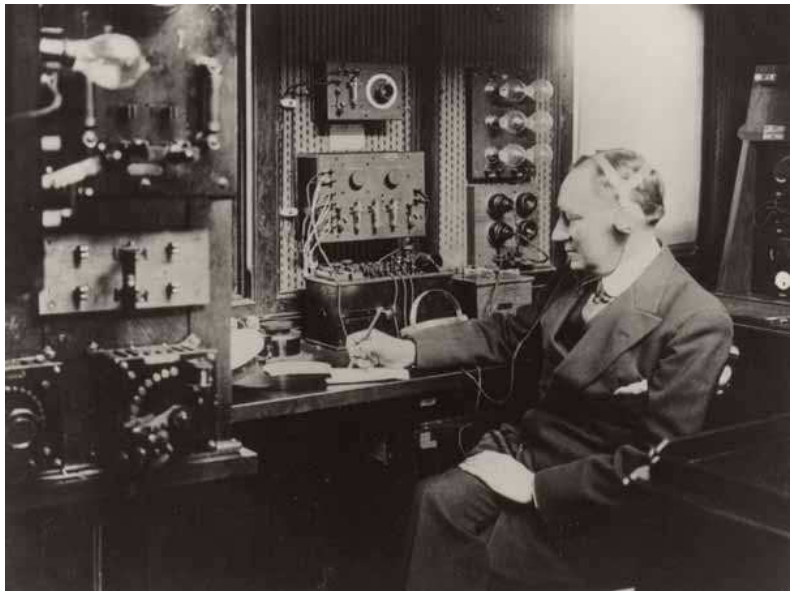
helmsman showing him whether he was to the left or right of the direct course leading to the "harbour" represented by the two buoys. The beacon also caused audible signals in a loud speaker by which he could set the course.

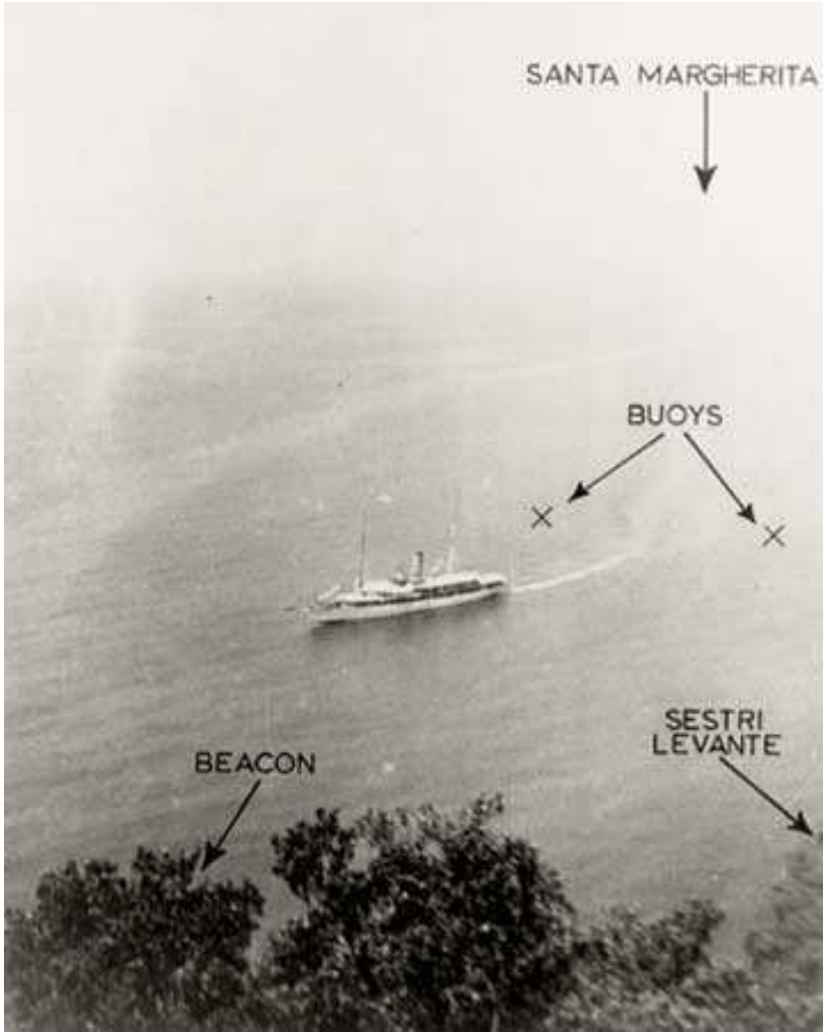
The yacht was piloted by an Englishman Commander Austin Bates, of the Cunard-White Star Line.

When the test was completed Commander Bates congratulated the

sends out two beams separated by a "beam of silence." These beams operate a needle on a dial in a ship. By this means the navigator can tell whether he is to the left or right of his correct course.

The birth of radio navigation





On that day of July more than seventy years ago, it saw the light an invention which would save thousands of lives and radically change transportation: radio navigation, that is, using radio waves as an aid to navigation.

From Marconi's experiments to current times

- **In the seventy years since Marconi's experiments in Sestri Levante, radio navigation has continuously evolved to affect more and more aspects of our daily life**
- **From the first terrestrial systems, based on the principle of "Radio Direction Finding" (RDF), the so-called "hyperbolic" systems were developed, which were used during the Second World War, such as the Loran-A, then followed by the Decca, Omega and Loran-C systems**
- **The need for global coverage systems providing greater localisation accuracy and a continuous service over time was not, however, completely fulfilled.**

4th October 1957, *19.28:34 GMT* : SPUTNIK-1 is launched

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

HOFFA IS ELECTED TEAMSTERS HEAD; WARNS OF BATTLE

COURSE RECORDED

Navy Picks Up Radio Signals—4 Report Sighting Device

560 MILES HIGH

Visible With Simple Binoculars, Moscow Statement Says

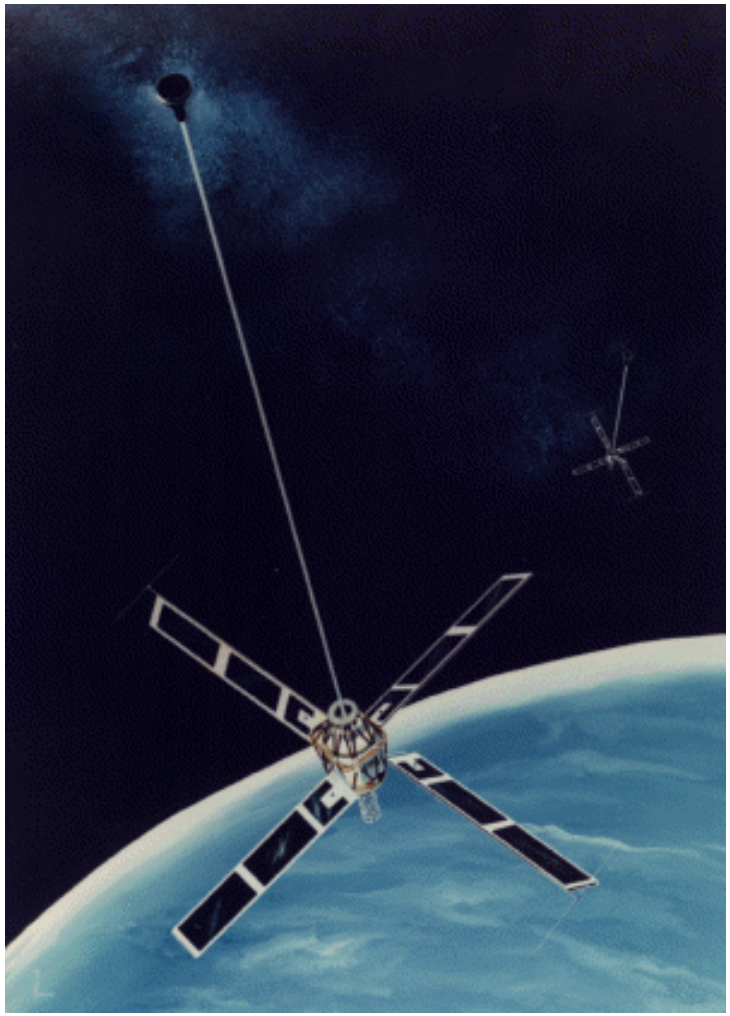
Device Is 8 Times Heavier Than One Planned by U.S.

Старт ракеты-носителя Р-7 с ИСЗ-1.
РГАНТД. Ф.211 оп.7 д.551.

Sputnik and the conception of navigation satellites

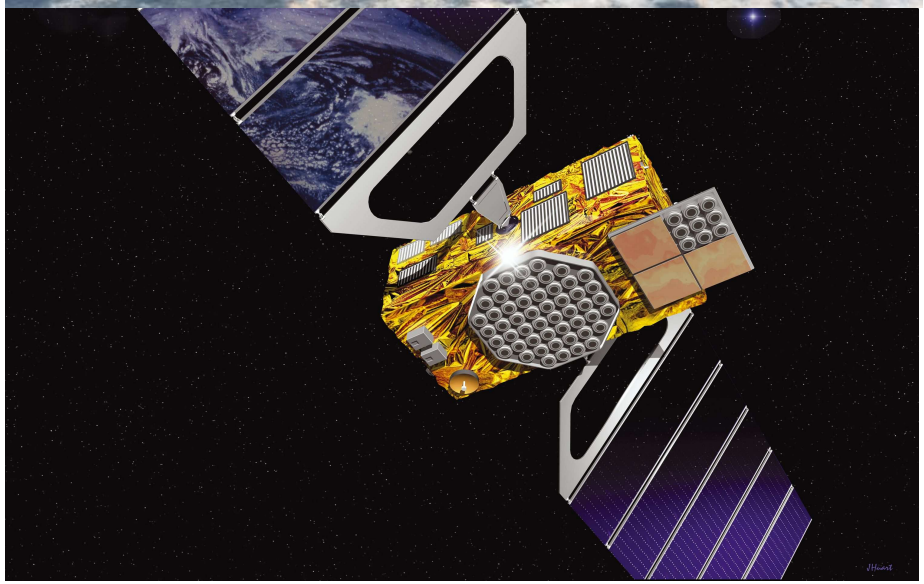
- After the launch of Sputnik-1 on Oct. 4, 1957, a small group of scientists at Johns Hopkins University's Applied Physics Laboratory (APL) started listening to variations caused by the Doppler effect in the satellite's 20 MHz signal, deducing its closest approach as well as other information about its orbit
- One of the scientists, Dr. Frank McClure, reasoned that the Doppler effect could also be used inversely to deduce the position of the receiver if the satellite's precise orbit were already known
- In 1958 the first satellite navigation project , Transit (or, more formally, the "Navy Navigation Satellite System") was started, under the management of the newly created Advanced Research Projects Agency (ARPA).

The Transit satellite navigation system

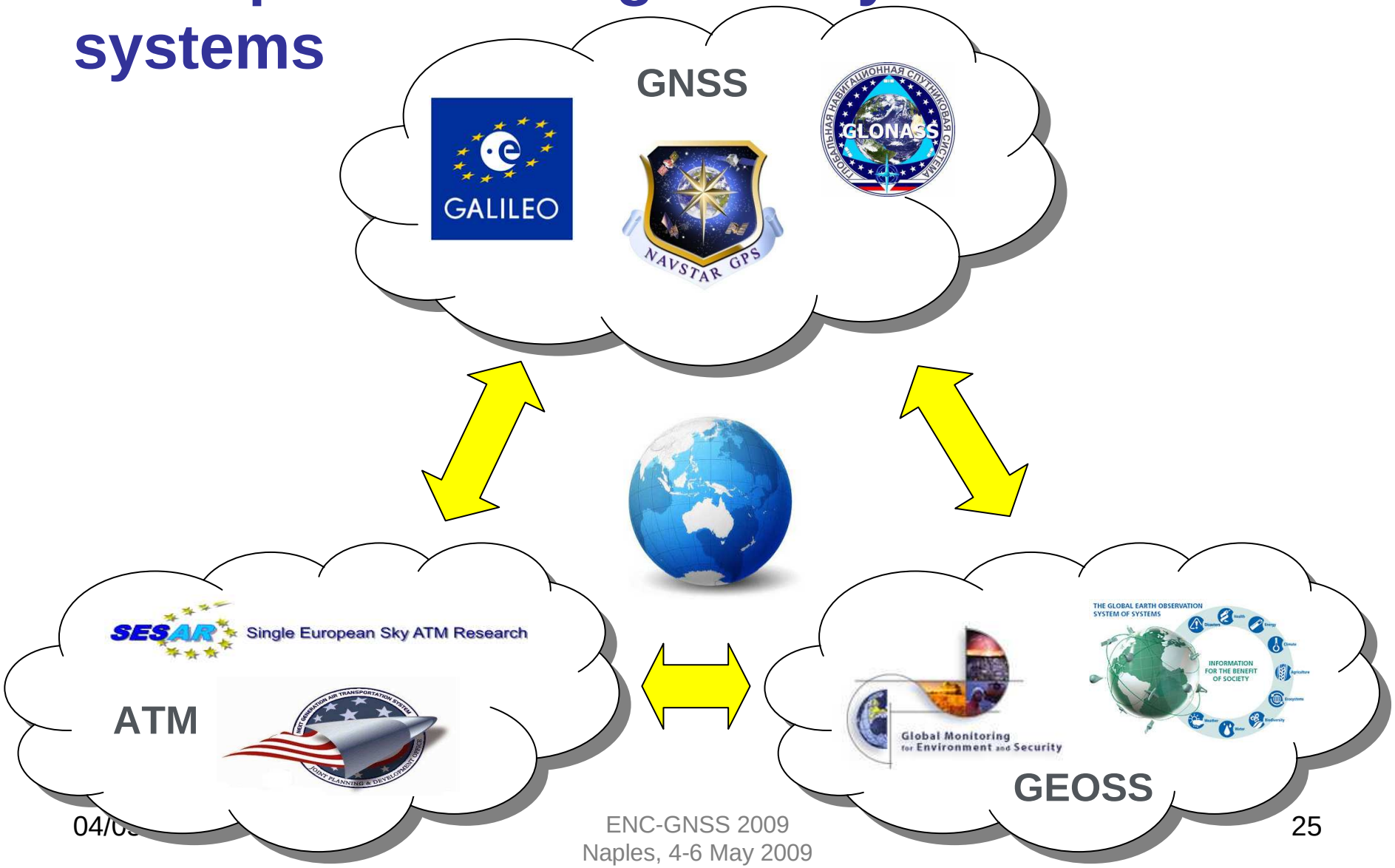


- **The Transit system consisted of a constellation of six satellites in a polar orbit with a nominal 600 nautical mile altitude, three ground control stations, and user receivers**
- **Transit entered Naval service in 1964 and in 1967 it was made available to commercial ships and aircraft of all nations**
- **In 1996 Transit, the Navy Navigation Satellite System, was retired after more than 32 years of continuous, successful service.**

Global Navigation Satellite Systems: GPS, GLONASS, GALILEO, BEIDOU



The future: a fully integrated and interoperable navigation system of systems



The not-so-far future: X-ray pulsars navigation system (XNAV)