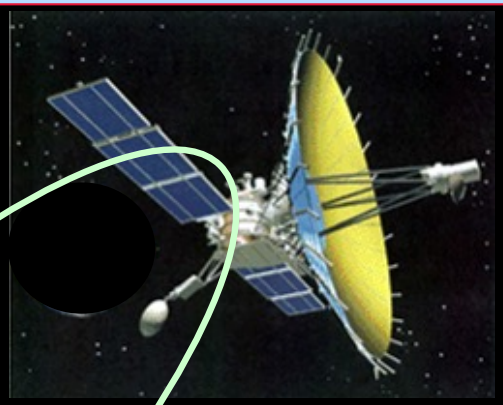
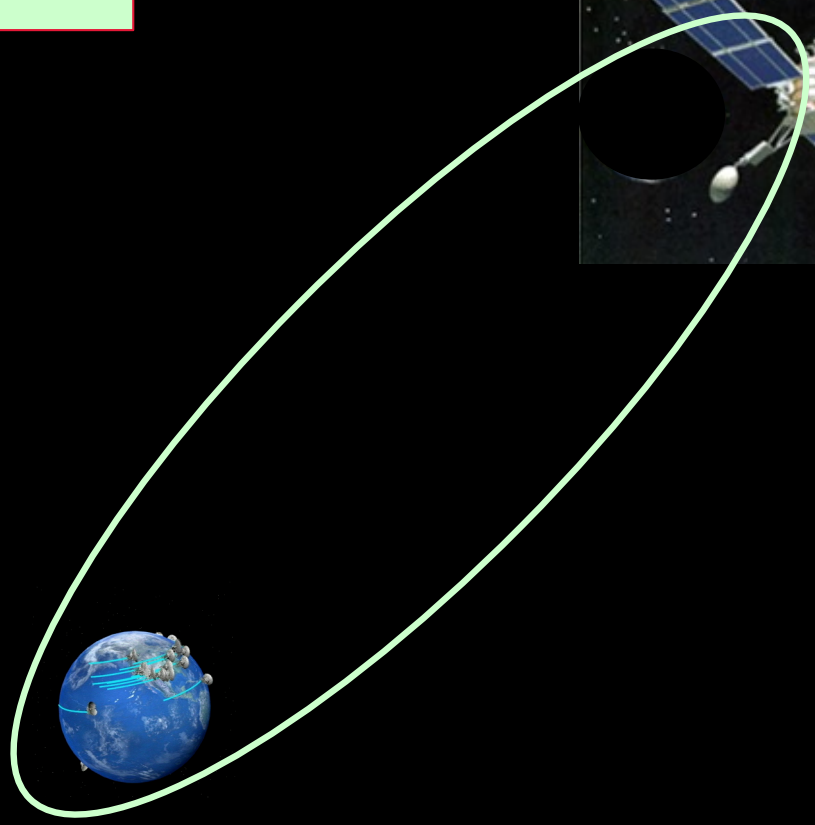
PHYS 3250 Introduction to space communications

1. History and overview of present status

Professor N. Bartel





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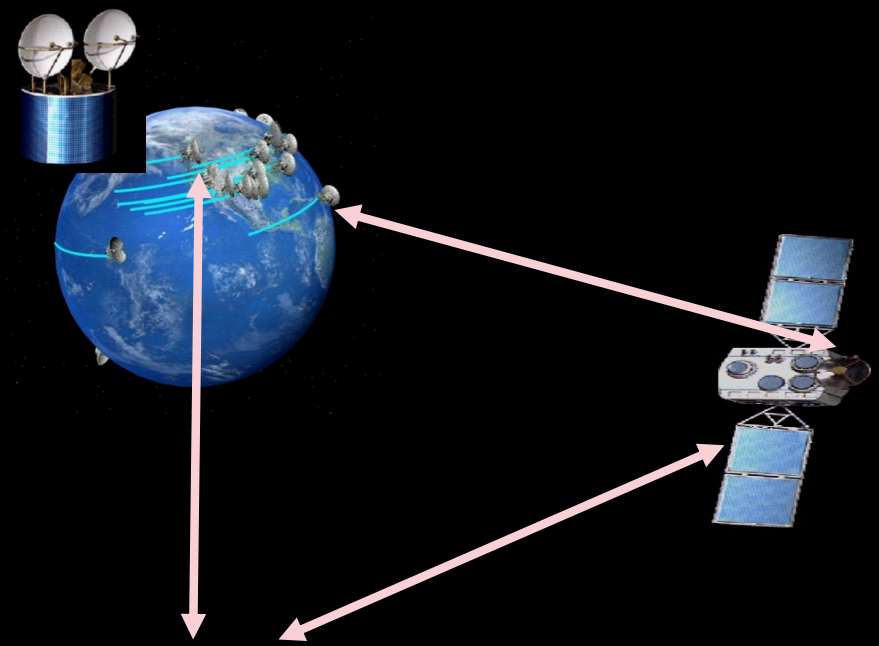
Space communications

communications between vehicles in outer space and Earth

with radio waves and in future with lasers too

- Satellite communications

  communications via (usually) Earth orbiting vehicles



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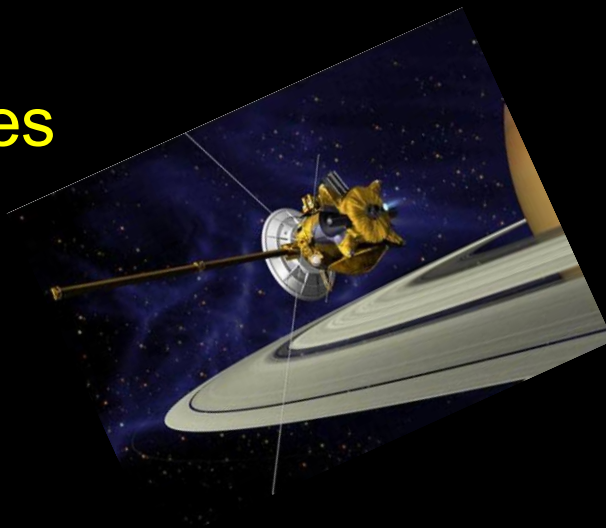
Space communications

communications between vehicles in outer space and Earth

- Deep space communications

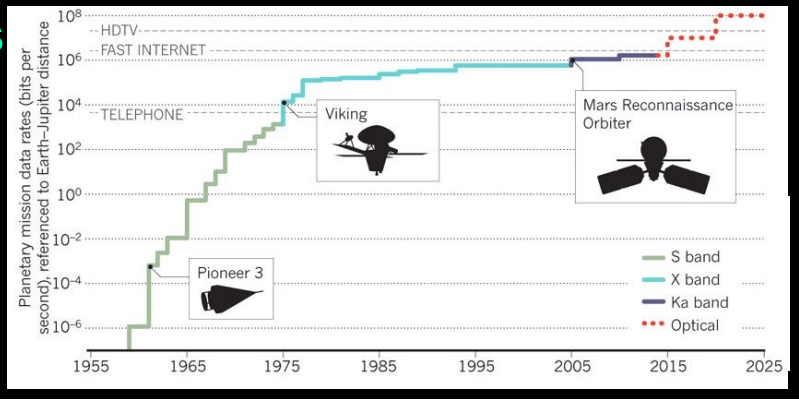
  communications via interplanetary vehicles

NASA Deep Space Station
(Goldstone, CA, 70m)



100 Mb/s

Improvements in deep space communications data rate



SPACE COMMUNICATIONS

Text book

- Title: Satellite Communications
- Author: Dennis Roddy
- ISBN: 0071371761
- Publisher: McGraw-Hill Professional
- Fourth Edition

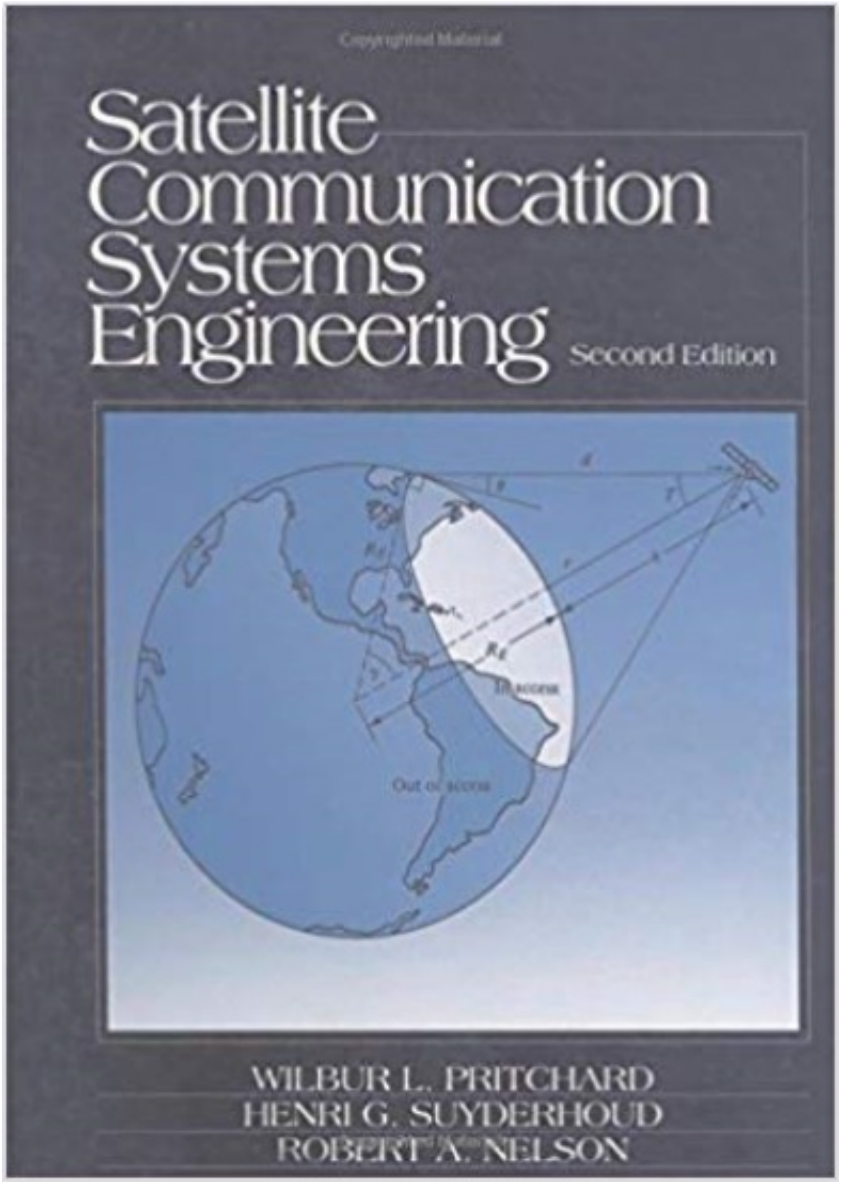
SPACE COMMUNICATIONS

Reference book

- Title: Satellite Communication Systems Engineering
- Author: W. L. Pritchard,

H. G. Suyderhoud, R. A. Nelson

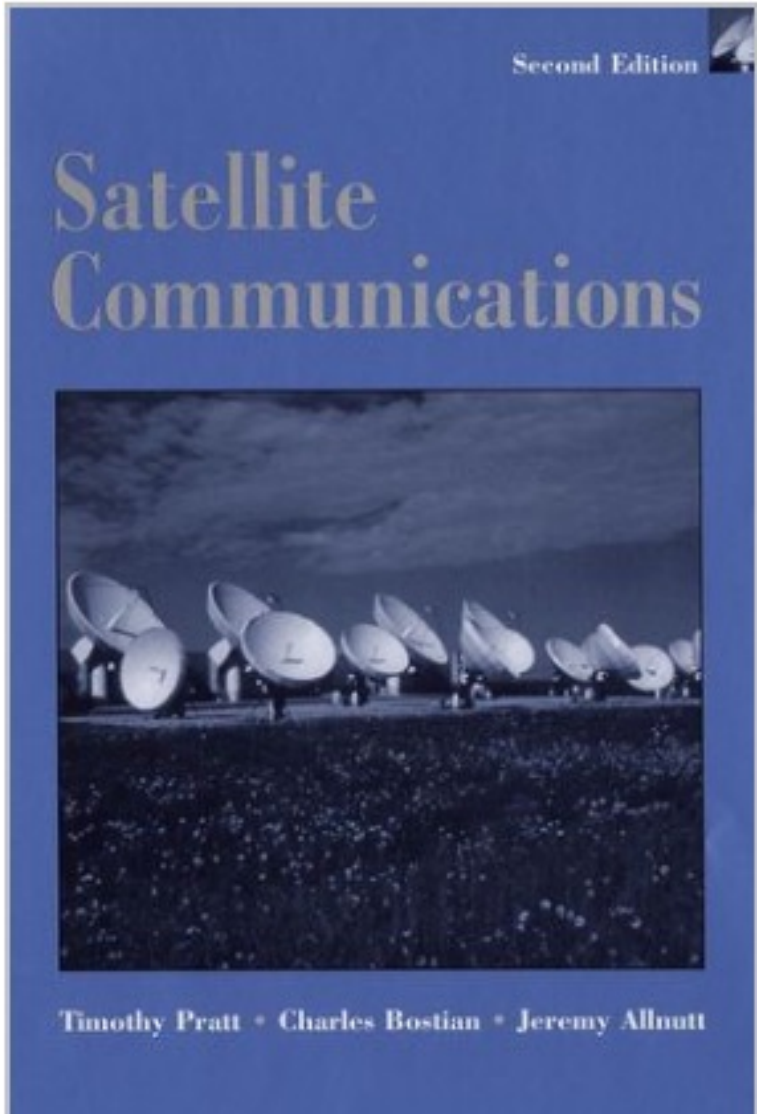
- ISBN: 0137914687
- Publisher: Prentice Hall
- 2*th* Edition



SPACE COMMUNICATIONS

Reference book

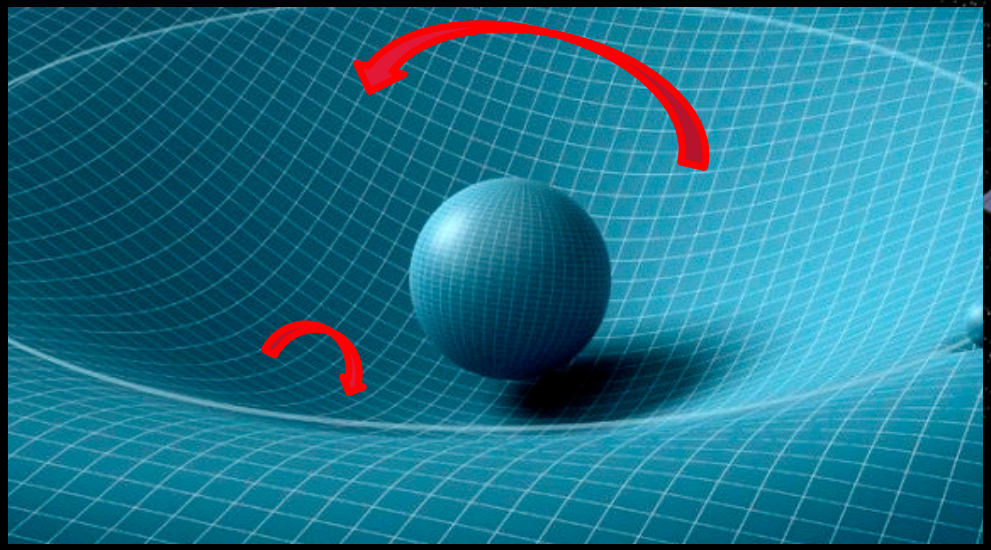
- Title: Satellite Communications
- Author: T. Pratt, C. W. Bostian
- ISBN: 978-0-471-37007-9
- Publisher: John Wiley & Sons
- 2*th* Edition
- 2002 Print

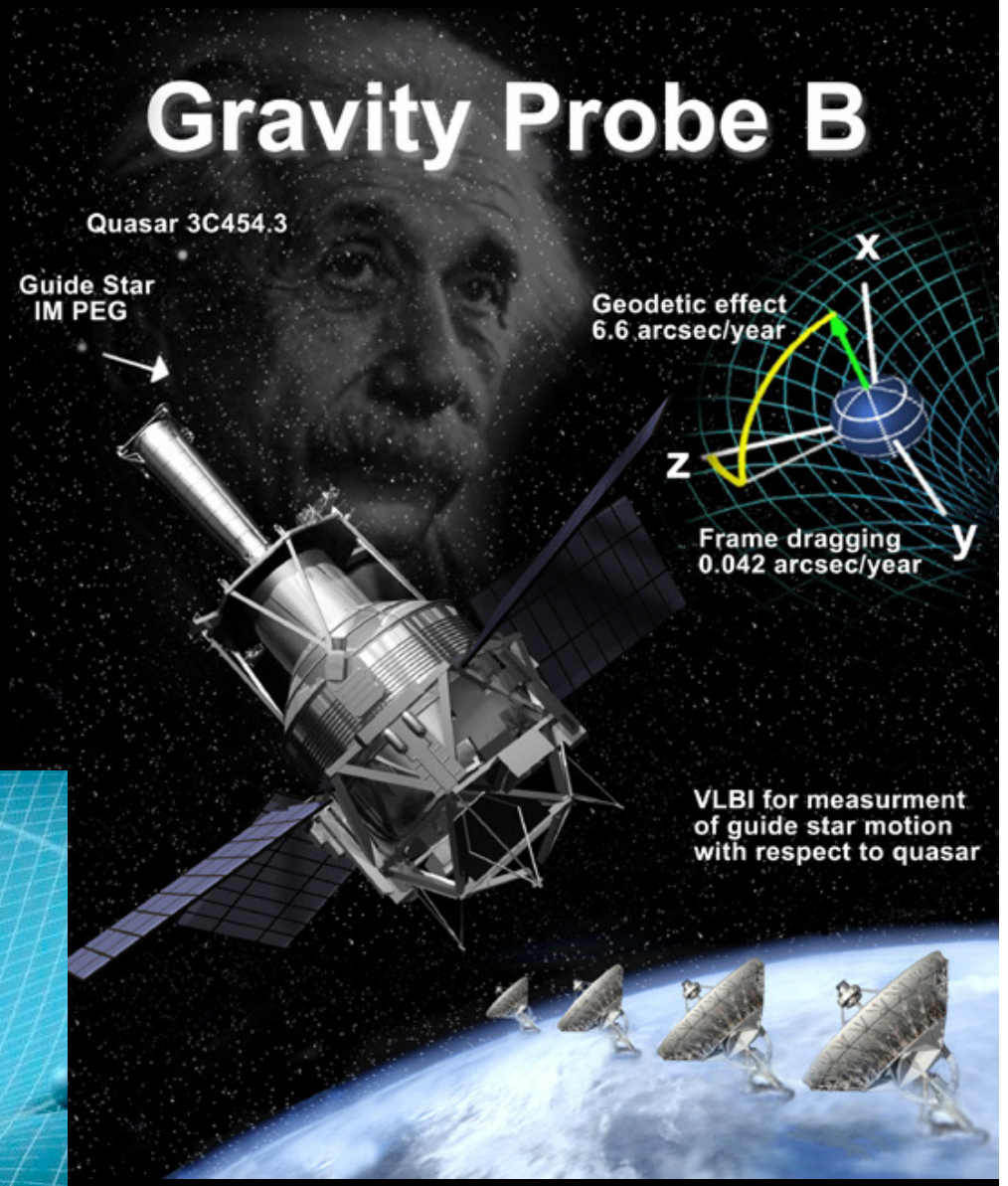


PHYS 3250
Introduction to space communications

Professor N Bartel

And his recent space projects





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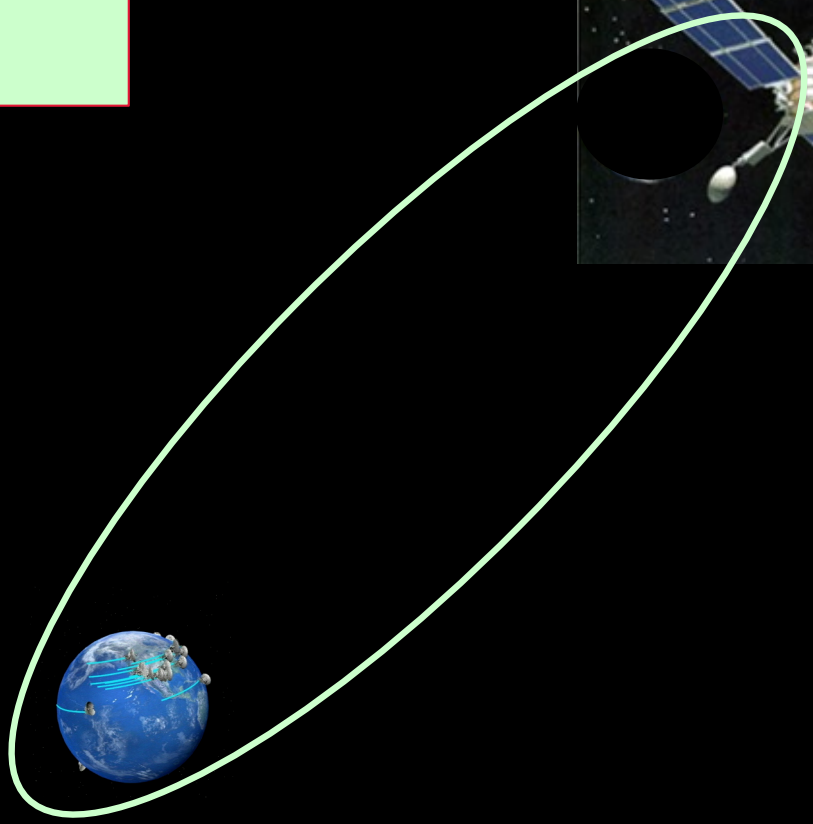
Introduction to space communications

Professor N Bartel

And his recent space projects



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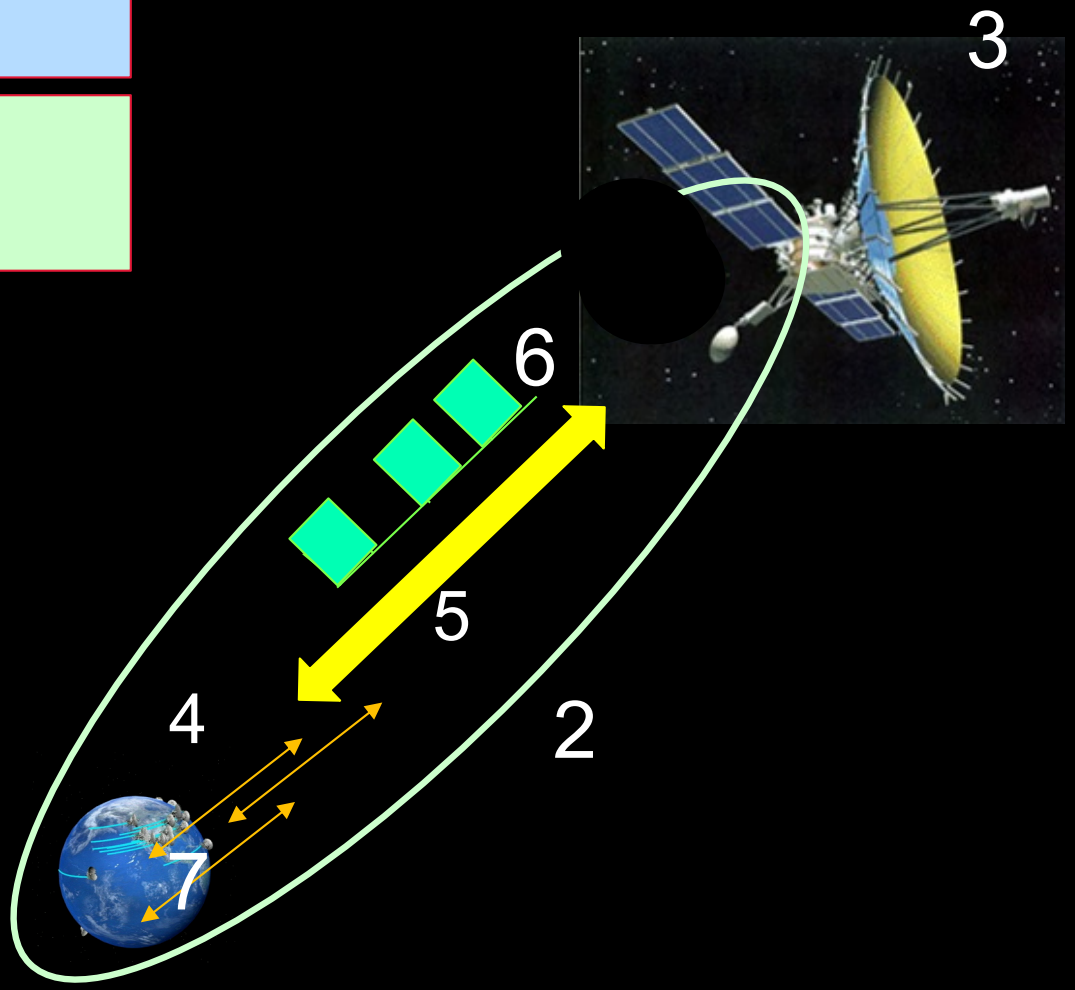
PHYS 3250
Introduction to space communications

Professor N Bartel

Sketch of the 7 chapters

2 Orbital aspects
3 Spacecraft
4 Earth station
5 Communications link
6 Modulation and multiplexing techniques
7 Multiple access to a satellite



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Earthbound communications systems

- 1837 First electric telegraph system, 1.5 km, in UK
- 1844 Samuel Morse demonstrated his telegraph code, in US
- 1868 First commercial transatlantic telegraph cable between UK and Canada
- 1901 Marconi transmitted first transatlantic wireless message from UK to Canada
- 1927 first commercial transatlantic radio telephone
- 1929 BBC started experimental TV
- 1936 first regular TV in UK and Germany

Wikipedia

Wikipedia

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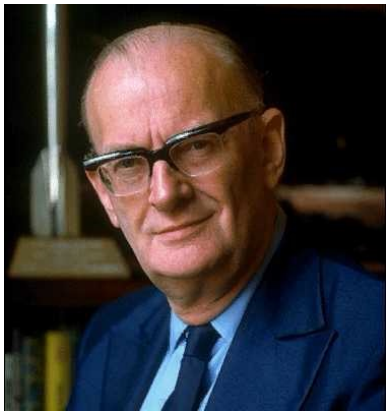
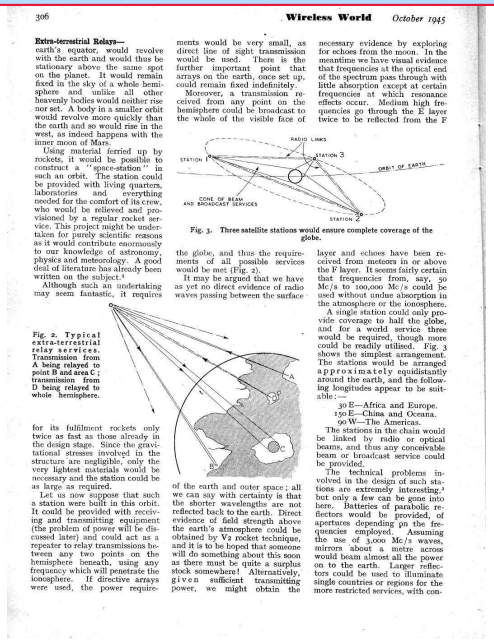
History of communications satellites

- 1945 Arthur C. Clarke proposed geostationary communications satellites with paper titled: “Extraterrestrial Relays” in the journal Wireless World. He calculated with $P^2 \alpha a^3$ that a satellite in circular orbit around Earth with a radius of 42,164 km on equatorial plane would have an angular velocity that matched the Earth’s angular velocity.

Three basic orbits: circular equatorial, circular polar, elliptical inclined




306 Wireless World October 1945

Extra-terrestrial Relays—

earth's equator, would revolve with the earth and would thus be stationary above the same spot on the planet. It would remain fixed in the sky of a whole hemisphere and unlike all other heavenly bodies would neither rise nor set. A body in a smaller orbit would revolve more quickly than the earth and so would rise in the west, as indeed happens with the inner moon of Mars.

Using material ferried up by rockets, it would be possible to construct a "space-station" in such an orbit. The station could be provided with living quarters, laboratories and everything needed for the comfort of its crew, who would be relieved and provisioned by a regular rocket service. This project might be undertaken for purely scientific reasons as it would contribute enormously to our knowledge of astronomy, physics and meteorology. A good deal of literature has already been written on the subject.[1]

Although such an undertaking may seem fantastic, it requires

Fig. 2. Typical extra-terrestrial relay services. Transmission from A being relayed to point B and area C; transmission from D being relayed to whole hemisphere.

for its fulfilment rockets only twice as fast as those already in the design stage. Since the gravitational stresses involved in the structure are negligible, only the very lightest materials would be necessary and the station could be as large as required.

Let us now suppose that such a station were built in this orbit. It could be provided with receiving and transmitting equipment (the problem of power will be discussed later) and could act as a repeater to relay transmissions between any two points on the hemisphere beneath, using any frequency which will penetrate the ionosphere. If directive arrays were used, the power requirements would be very small, as direct line of sight transmission would be used. There is the further important point that arrays on the earth, once set up, could remain fixed indefinitely.

Moreover, a transmission received from any point on the hemisphere could be broadcast to the whole of the visible face of

Fig. 3. Three satellite stations would ensure complete coverage of the globe.

the globe, and thus the requirements of all possible services would be met (Fig. 2).

It may be argued that we have as yet no direct evidence of radio waves passing between the surface of the earth and outer space; all we can say with certainty is that the shorter wavelengths are not reflected back to the earth. Direct evidence of field strength above the earth's atmosphere could be obtained by V2 rocket technique, and it is to be hoped that someone will do something about this soon as there must be quite a surplus stock somewhere! Alternatively, given sufficient transmitting power, we might obtain the necessary evidence by exploring for echoes from the moon. In the meantime we have visual evidence that frequencies at the optical end of the spectrum pass through with little absorption except at certain frequencies at which resonance effects occur. Medium high frequencies go through the E layer twice to be reflected from the F layer and echoes have been received from meteors in or above the F layer. It seems fairly certain that frequencies from, say, 50 Mc/s to 100,000 Mc/s could be used without undue absorption in the atmosphere or the ionosphere.

A single station could only provide coverage to half the globe, and for a world service three would be required, though more could be readily utilised. Fig. 3 shows the simplest arrangement. The stations would be arranged approximately equidistantly around the earth, and the following longitudes appear to be suitable:—

30 E—Africa and Europe.
150 E—China and Oceana.
90 W—The Americas.

The stations in the chain would be linked by radio or optical beams, and thus any conceivable beam or broadcast service could be provided.

The technical problems involved in the design of such stations are extremely interesting,[2] but only a few can be gone into here. Batteries of parabolic reflectors would be provided, of apertures depending on the frequencies employed. Assuming the use of 3,000 Mc/s waves, mirrors about a metre across would beam almost all the power on to the earth. Larger reflectors could be used to illuminate single countries or regions for the more restricted services, with con-

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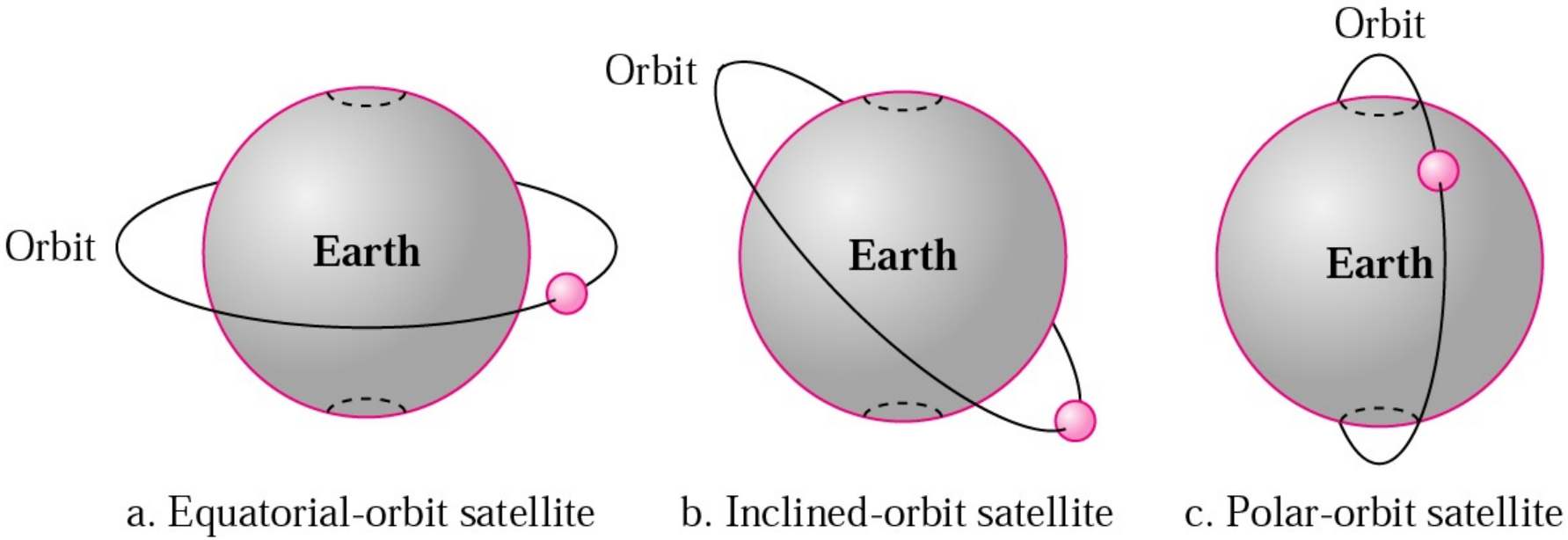
Satellite orbits

Three basic orbit planes:



a. Equatorial-orbit satellite b. Inclined-orbit satellite c. Polar-orbit satellite

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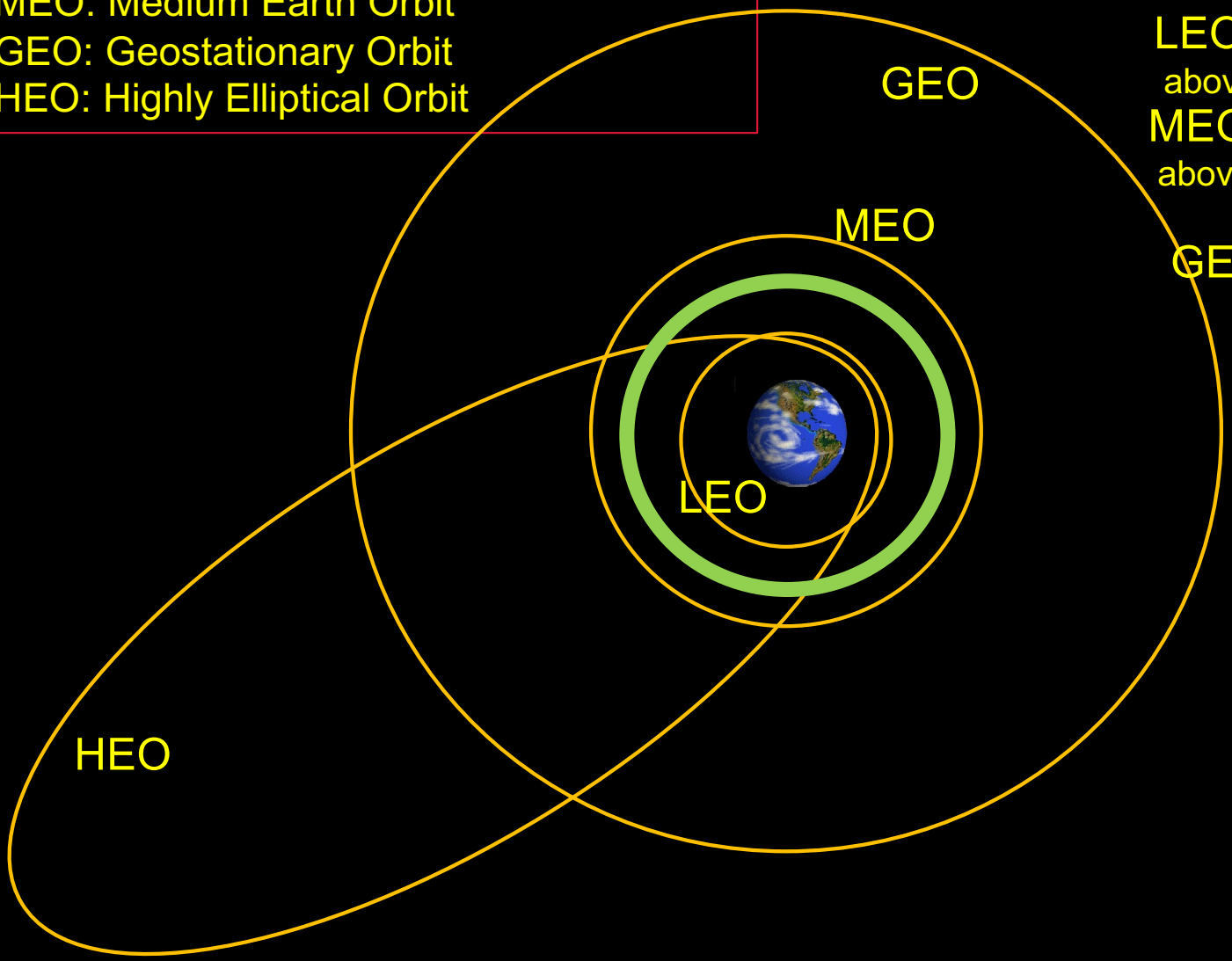
Satellite orbits

Four basic orbit heights and shapes:
LEO :Low Earth Orbit
MEO: Medium Earth Orbit
GEO: Geostationary Orbit
HEO: Highly Elliptical Orbit



Van Allen radiation belts
to be avoided

LEO: R= 500 - 1500 km
above surface, visible 15-20min

MEO: R=8000-20000 km
above Earth surface, visible: 2-8h

GEO: R= 42164 km
from Earth center visible 24h

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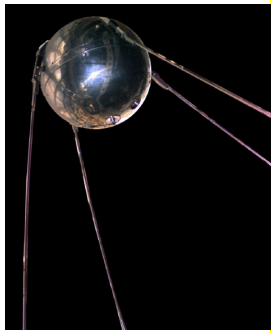
- 1955 J.R. Pierce defined parameters for satellite communications
- 1957 Launch of Sputnik – first artificial satellite (USSR)
- 1960 Launch of Echo I, first communications satellite, AT&T, 30m diameter ballon in low-earth orbit (LEO)

  with P=118 min.
- 1962 Launch of Telstar I, first commercially funded communications satellite, AT&T,elliptical LEO orbit, broadband real-time transponder
- 1962 Launch of Alouette Canada's first satellite (ionosphere studies)
- 1963 Launch of Syncom II, first geostationary communications satellite
- 1964 INTELSAT organisation established



Sputnik
Wikipedia

https://www.nasa.gov/centers/langley/about/project-echo.html

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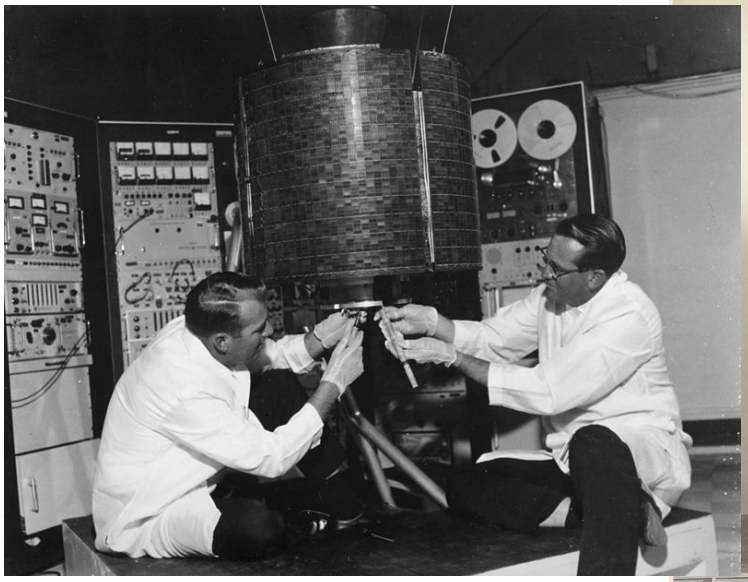
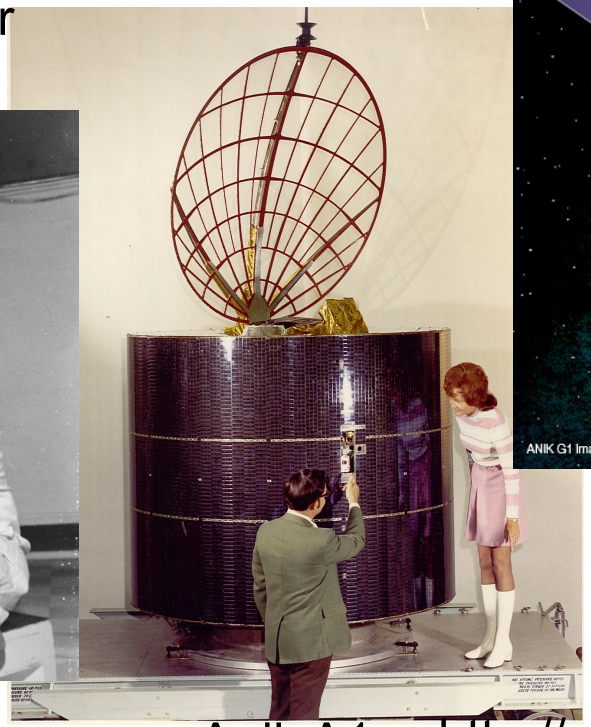
- 1965 Launch of INTELSAT I “Early Bird”
- 1965 Launch of Molniya (USSR), first domestic communications satellite, highly elliptical orbit with apogee height of 40,000 km.
- 1972 Launch of Anik A1, Canada’s first communications satellite, and first domestic communications satellite placed in geostationary orbit.
- 2013 Launch of Anik G1

Anik: little brother



INTELSAT I, wikipedia



Anik A1, http://www.asc-csa.gc.ca

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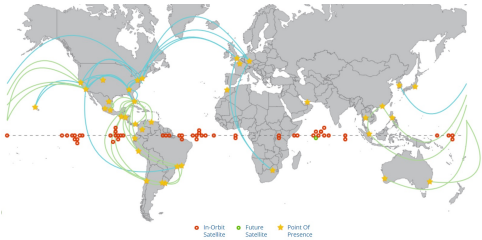
Global services

- INTELSAT (International Telecommunications Satellite organization)
  - 149 member countries
  - INTELSAT 36 (last satellite), geostationary orbits

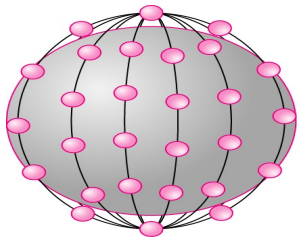


- INMARSAT

  (internat. maritime satellite organization)
  Sets of 4 geostationary satellites
  70% coverage but not the poles

- Iridium

  66 active satellites in polar LEOs
  100% global coverage
  Accessible with handheld devices (expensive)



- Starlink 1000's of small satellites in LEOs for high speed internet everywhere

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Regional services

- EUTELSAT (European Telecommunications Satellite organization)
- ARABSAT (has about 20 members of the Arab league)
- PALAPA (service for Indonesia and the Philippines)

Domestic services

…lots of them now.

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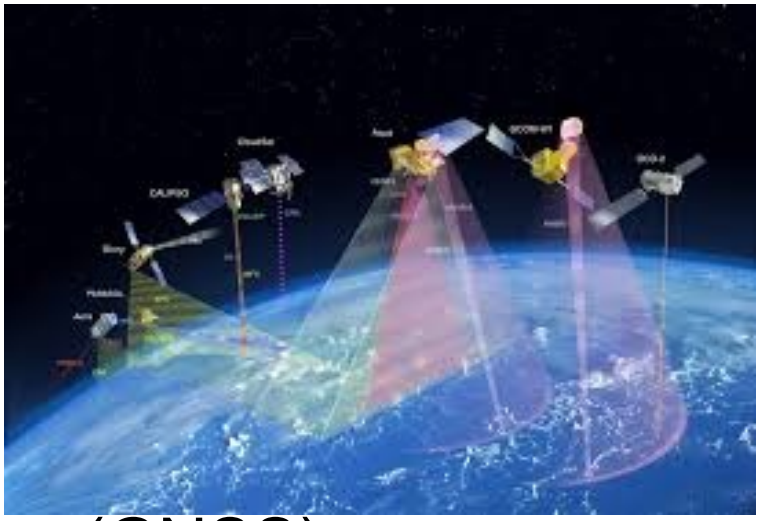
Other Earth-orbit Satellites

- Military satellites (very) LEO
- Remote sensing satellites,
  (Radarsat, many others)



wikipedia

- Global Navigation Satellite Systems (GNSS)
  - GPS (US),
  - GLONASS (Russia),
  - Galileo (Europa).
  - BeiDou (China),
  - NAVIC (India),
  - Quasi-Zenith (Japan)
- Research satellites (HST, GP-B, RadioAstron, and many more..

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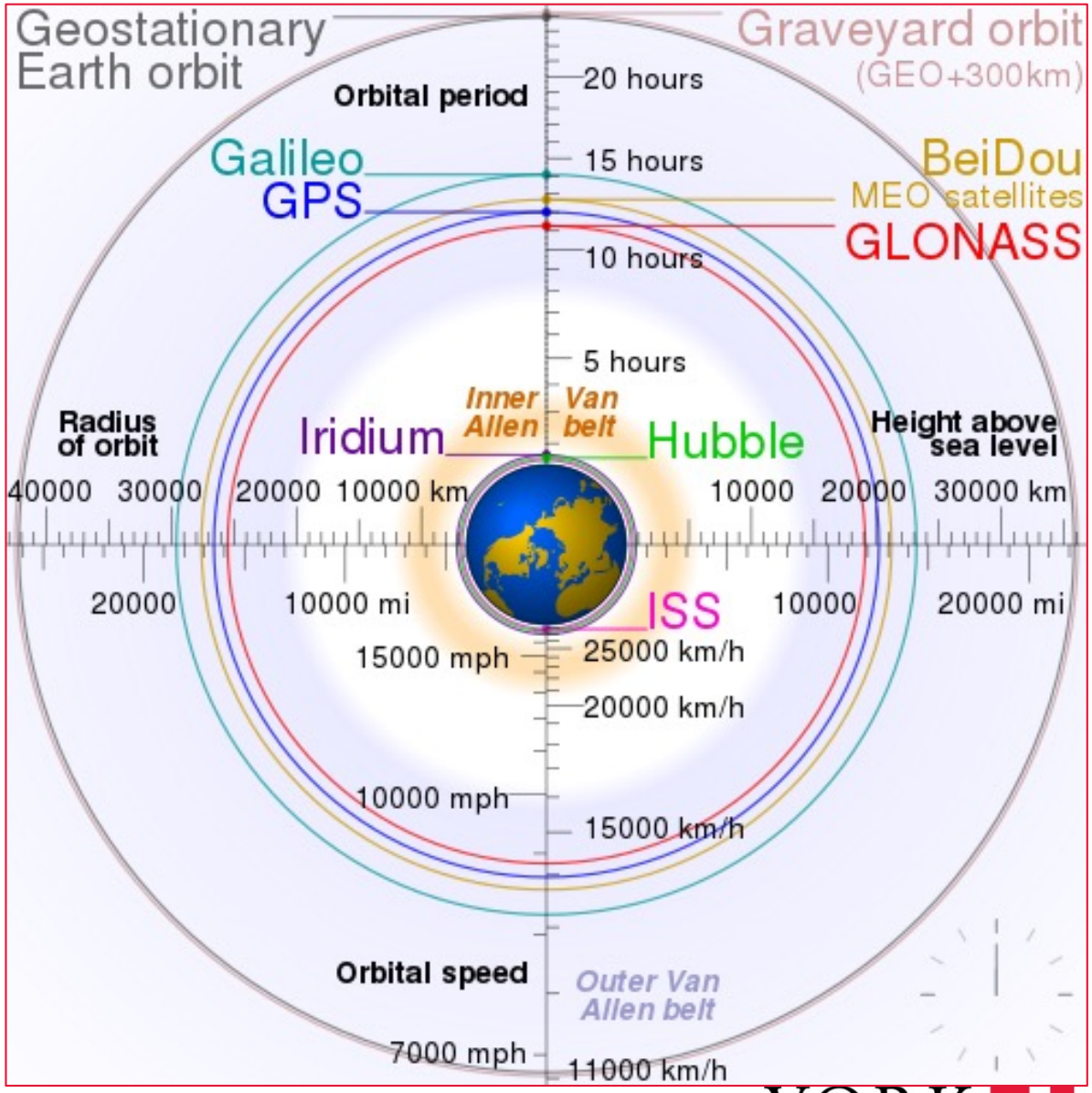
Global Navigation Satellite System (GNSS)



- GPS : USA
- GLONASS: Russia
- Galileo:EU
- BeiDou:China

Wikipedia

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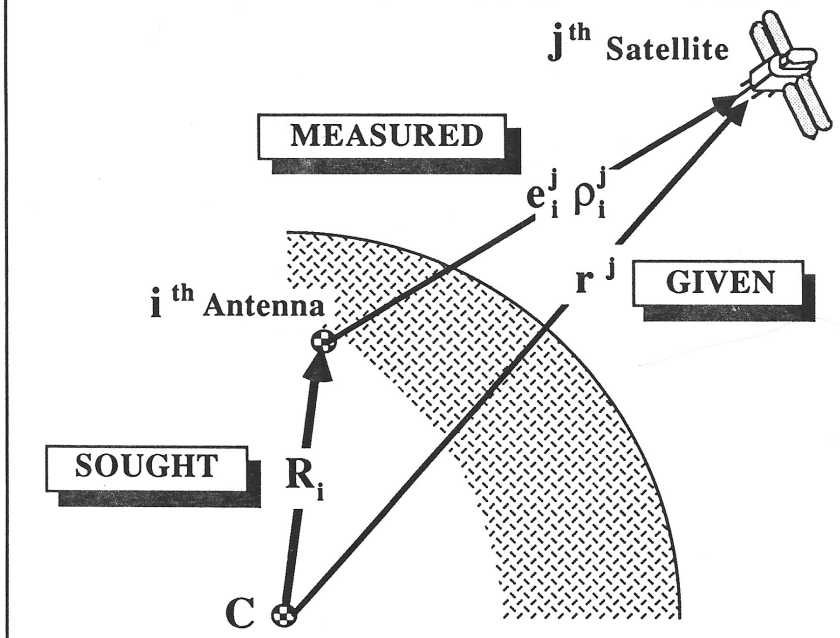
BASIC CONCEPT OF SATELLITE POINT POSITIONING

1.07



$$R_i = r^j - e_i^j \rho_i^j$$

R_i is the position vector of the i th antenna

r^j is the position vector of the j th satellite

$e_i^j \rho_i^j$ is the range vector between the two.

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Who volunteers to be the class representative?

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Latest Interplanetary spacecraft: Parker Solar Probe

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- Further information is on Chapter 1, lecture notes.