



LECTURE

5

Supplement to

Global navigation satellite
systems (GNSS)

Recapitulation

Satellite navigation systems

History of satellite navigation – USA



USA

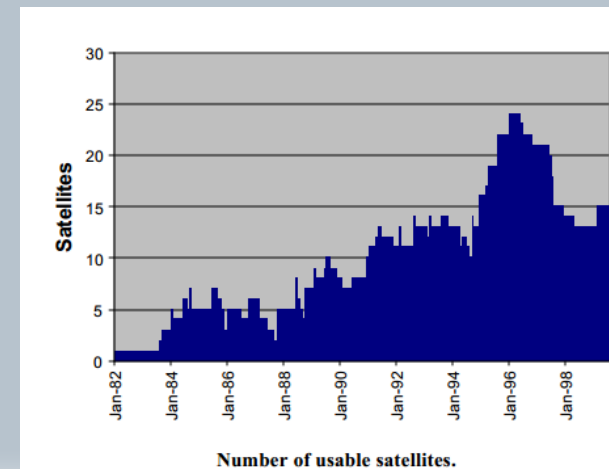
- 1960 – TRANSIT system, 5 satellites, Doppler effect, without clocks, fix once per hour,
- 1960 – proposal for MOSAIC system (3D LORAN), following study Project 57 (1963) formed basics for GPS. Further study Project 621B
- 1974 – first atomic clock on the 3rd satellite of the Timation project
- 1974 – Navstar concept (based on previous research)
- Till 1989 test satellites, 1989 first satellite of the GNSS system, 24 satellites launched till 1994 – complete constellation
- **1994 – Navstar-GPS system in operation** (uses WGS84)
- Uses CDMA for navigation signal transmission

History of satellite navigation – SSSR



SSSR

- CIKADA, Doppler effect, without clock, fix once per hour,
- **GLONASS**, similar to Navstar-GPS, development from 1976,
- 1984 – first satellites launched
- Global coverage 1991, 1995 full constellation, afterwards period of non function, since 2010 fully functional (21/24 satellites in operation)
- Uses PZ-90 system (Parametry Zemli 1990)
- Uses FDMA



History of satellite navigation - Europe



Europe

- **LOCSTAR** not-realized (ends 1991, plan of using 4 satellites of GOSTAR project and launch more)
- **GRANAS** (Global Radio Navigation Satellite), not-realized. Concept more simple than GPS
- **NAVSAT** not-realized, plan using GRANAS and NAVSTAR,
- **EUTELTRACS** European mutation OMNITRACS. For mobile communication. Uses telecommunication EUTELSAT satellites.
- **GALILEO** – future navigation system of the European union (now 6 satellites in orbit)
 - Expected in operation 2020?
 - In full constellation 30 satellites (27 navigation, 3 spares)

History of satellite navigation – Asia

China

- **COMPASS** – 35 satellites planned.(5 satellites geostationary, 27 Medium Earth Orbit, 3 IGSO (IGSO)).
- Now app. 19 satellites in orbit (2015)
- Expected in operation in 2020

• Japan

- QZSS (Quasi Zenith Satellite System in Japan)
- under development, 3 satellites planned
- First satellite „Michibiki“ launched 11. September 2010
- Full operation planned for 2017

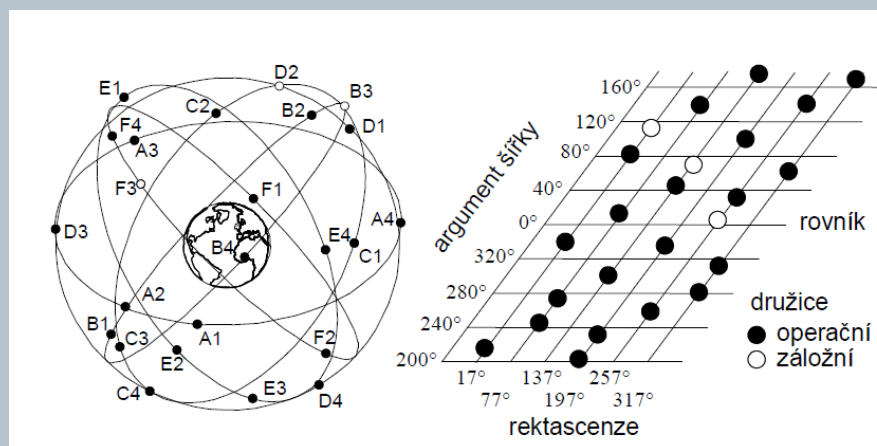


Other

- E.g. Plan for local satellite navigation system in India, etc.

Architecture – Navstar-GPS

- Global positioning system – for positioning anywhere on Earth
- Uses telemetric method for positioning
- Consists of 3 segments
 - cosmic,
 - control,
 - user.



Architecture – Navstar-GPS

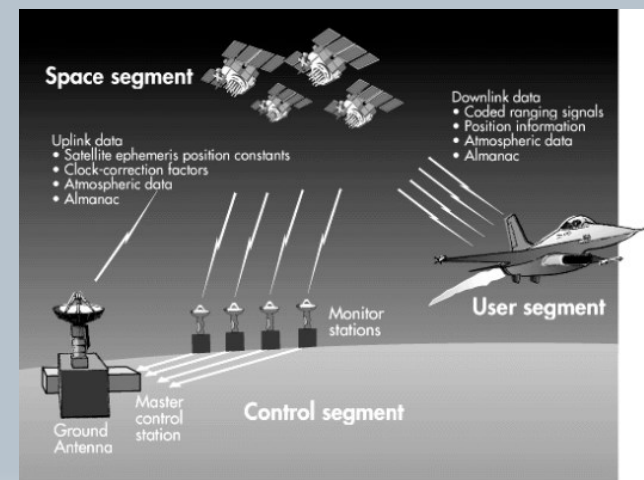
Cosmic segment

- Consists of **24** satellites, altitude 20 190 km, in 6 orbits
- satellites complete an orbit in 11 h 58 min, speed 3,8 km/s
- Key NAVSTAR satellites components:
 - 3 or 4 very accurate (10^{-13} s) atomic clocks with rubidium (formerly cesium oscillator)
 - 12 RHCP antennas for transmission radar codes in the L-band (2000-1000 MHz)
 - Antennas for communication with earth control stations in the S-band (2204,4 MHz)
 - Antennas for mutual satellites communication in the UHF band
 - Optic, x-ray and pulse electromagnetic detectors and sensors for detection of missiles launch and nuclear blasts
 - Solar panels and batteries as the energy source

Architecture – Navstar-GPS

Control segment

- Main control station (MCS) located in Colorado Springs
 - MCS communicates / controls the satellites, counts orbiting parameters, clock parameters, variations (ionospheric refraction) and sends them to the satellites
- monitoring stations delivering data to MCS



Error sources

- **Approximate values**
 - Ionosphere propagation 4,0-10 m
 - Troposphere propagation 0,7 m
 - Clock inaccuracies 2,0 m
 - Noise 0,5 m
 - Efemerids 2,1 m
 - Calculation, rounding errors 0,5 m
 - Multipath effect 1,0 m

Total error may be up to 15 m