(Kostnads)effektiva mätningar med Galileo

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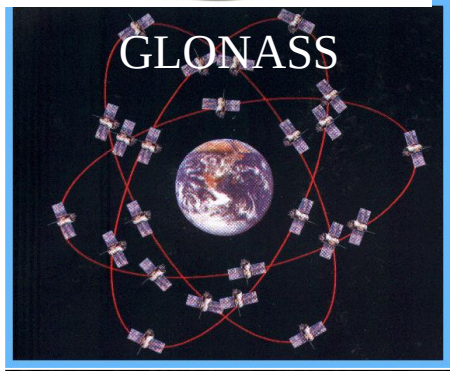
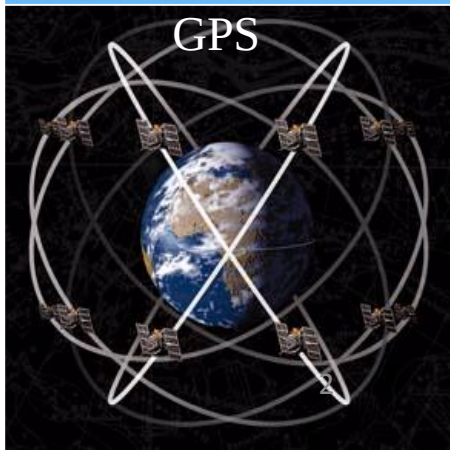
GNSS - Global Navigation Satellite Systems

- Sputnik (50-tal)
- Transit/Doppler (60-tal)
- Global Positioning System (USA, 70-tal)
- GLONASS (Ryssland, 70-tal, 2000-tal)
- Galileo (Europa, 2000-tal)
- Beidou (Kina, 2000-tal)

- **GNSS - Global Navigation Satellite Systems**
- Regionala system (EGNOS, WAAS, SBAS, QZSS, IRNNS mm)

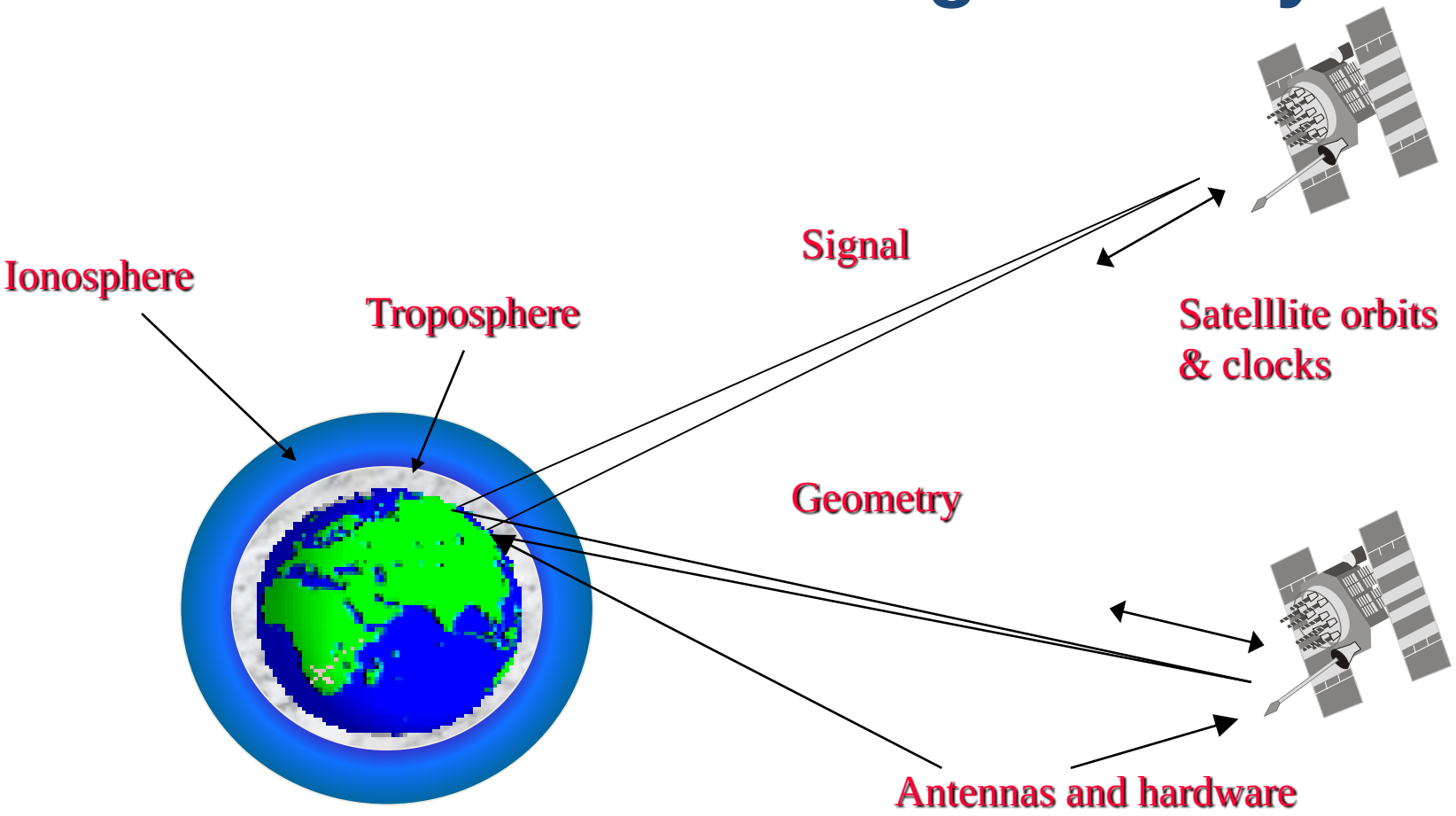




GNSS-utvecklingen (något tillspetesad)

- dm-nivå med veckors fördröjning, m-nivå i realtid på 1980-talet
- cm-nivå med veckofördröjning, många cm i realtid på 1990-talet
- mm-nivå med veckofördröjning, cm-nivå samma dag, realtid några cm på 2000-talet
- mm-nivå i nära realtid, cm-nivå i realtid 2010-talet
- Sub-mm i efterberäkningar och mm-nivå i realtid???

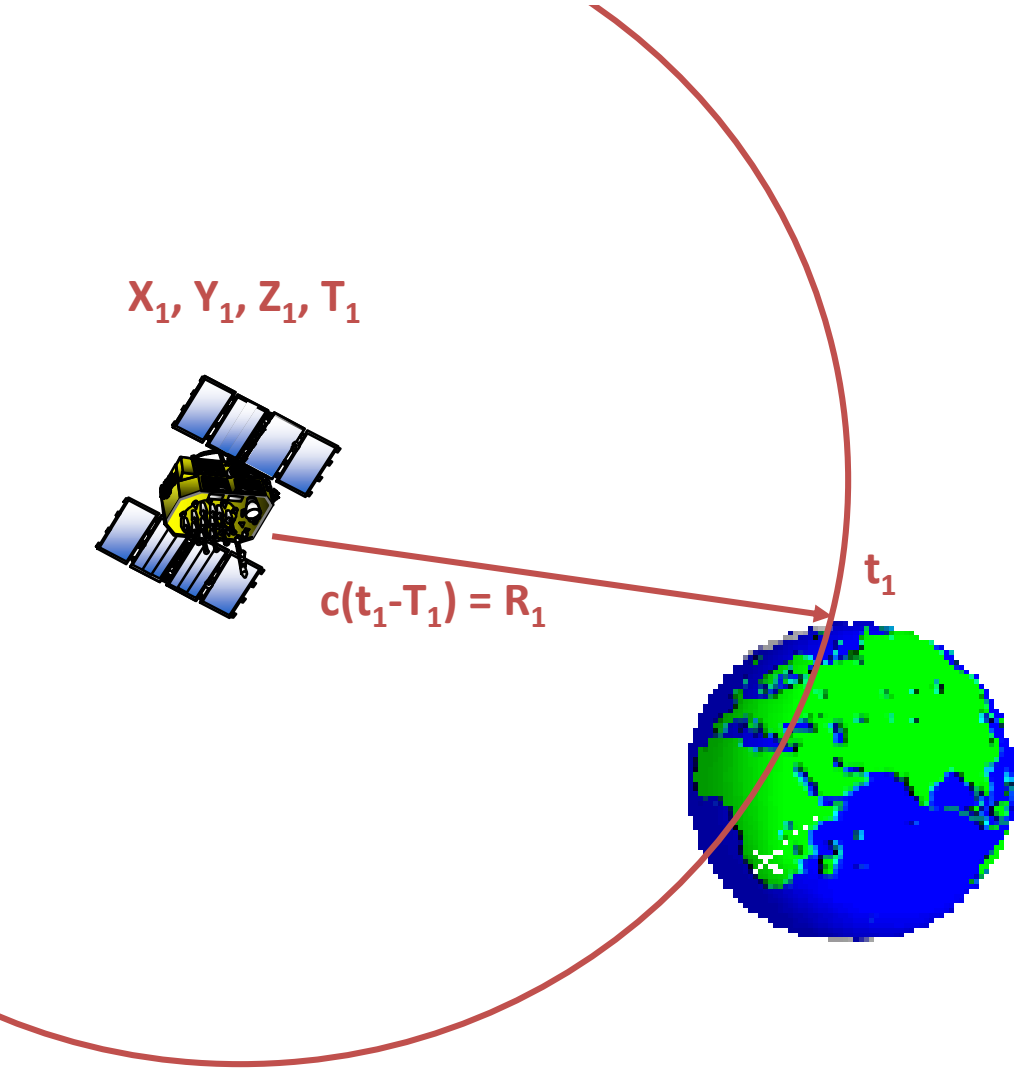
Satellitbaserade navigationssystem



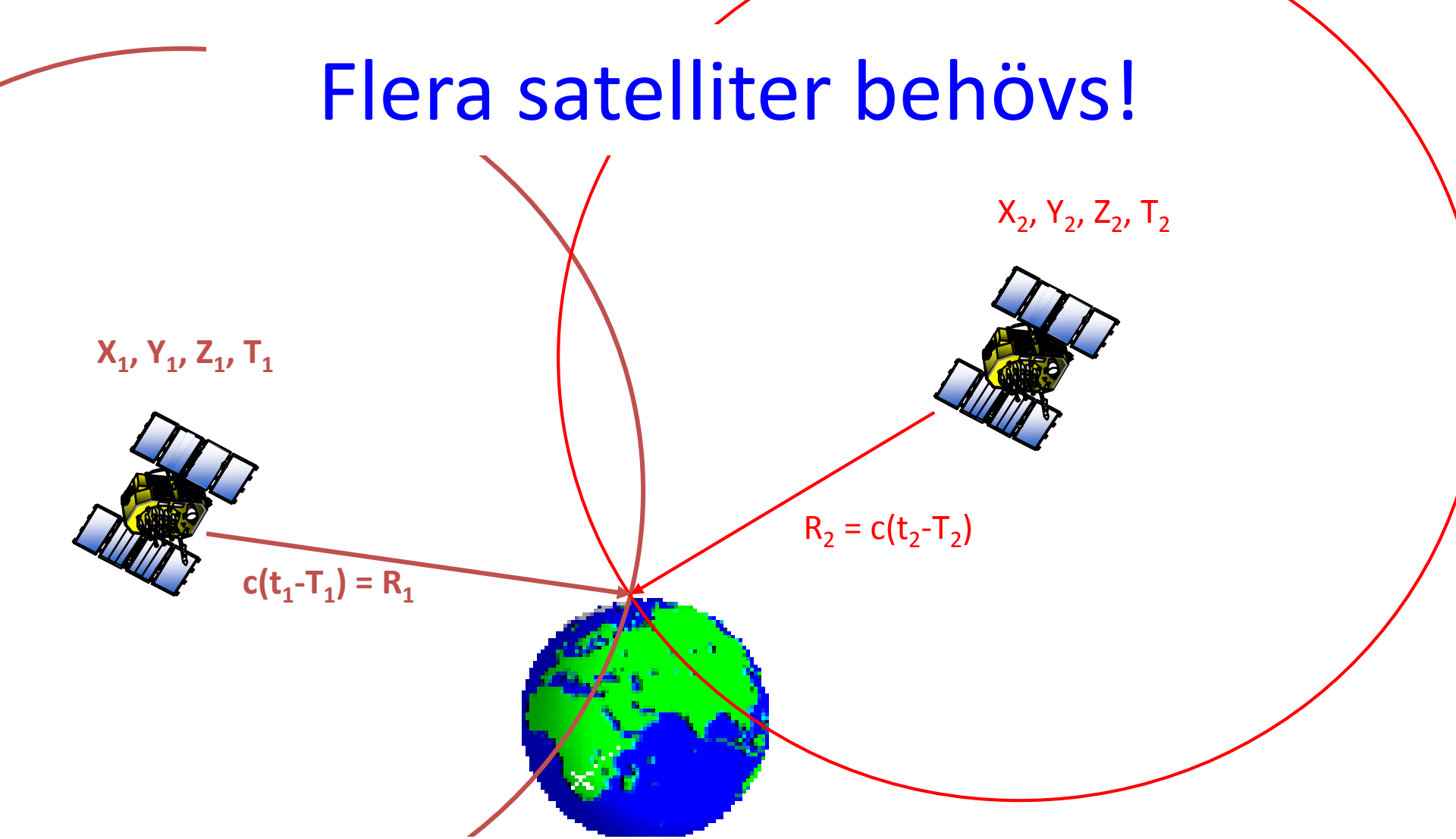
1. Satellites
2. Ground stations
3. Users

3 segments in GNSS

Hur fungerar GNSS?

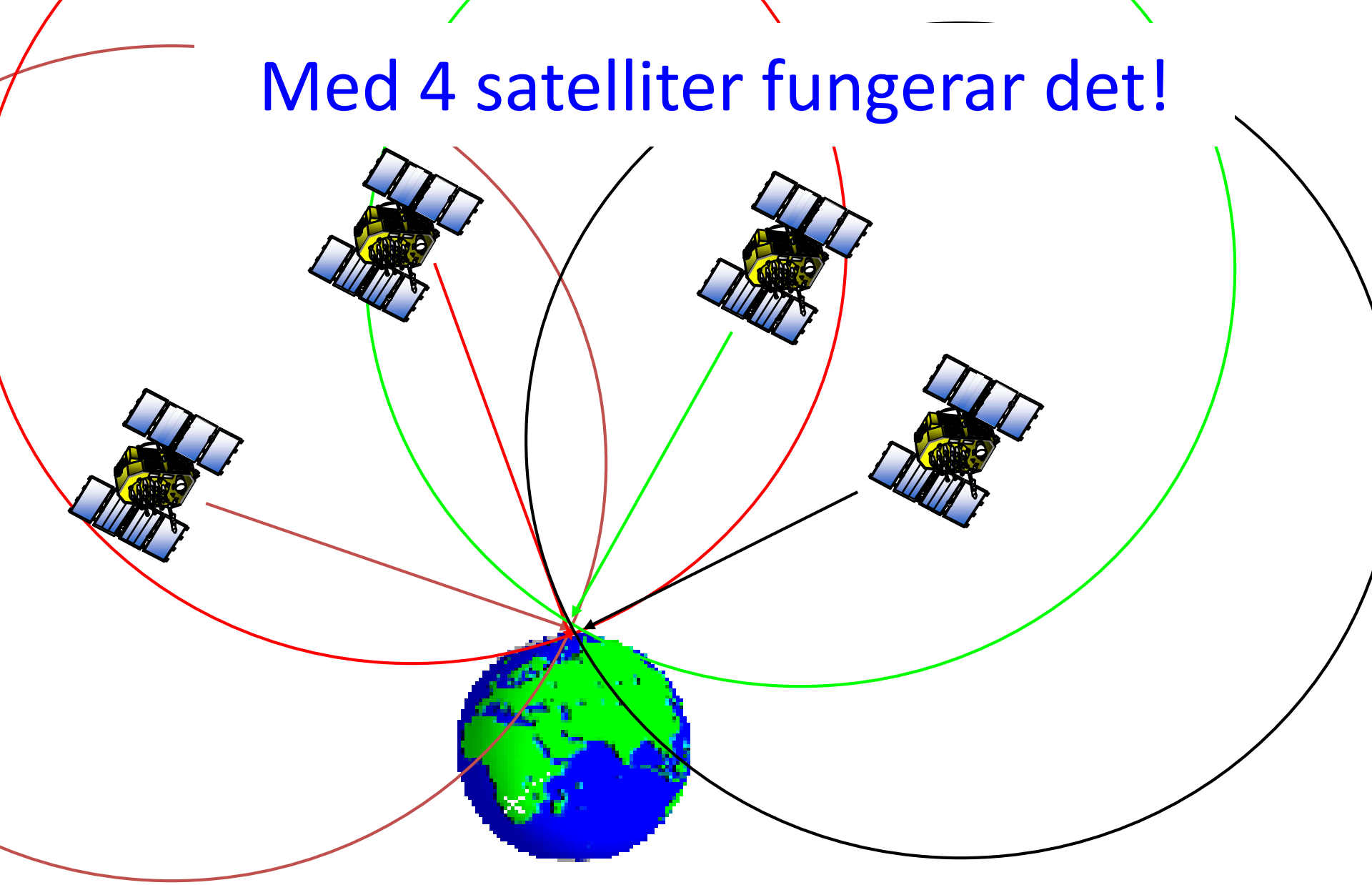


Flera satelliter behövs!

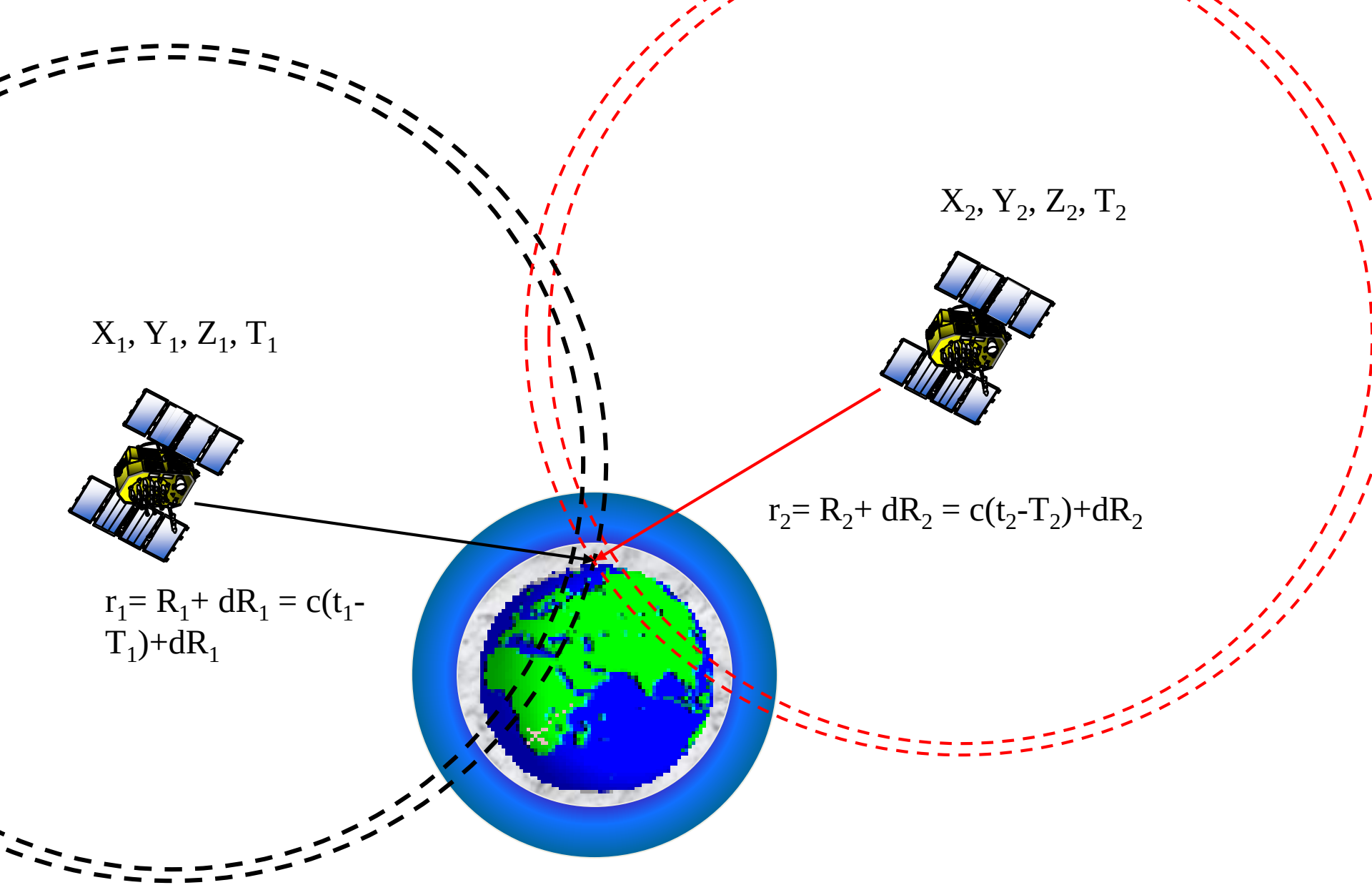


Signalen går ungefär med ljusets hastighet dvs 300 000 000 meter/sekund
Avståndet till satelliten är 20 000 000 meter eller mer
För att kunna mäta avstånd med en noggrannhet av 3 meter krävs att tidmätningen i mottagaren kan göras med en noggrannhet av 10 nanosekunder

Med 4 satelliter fungerar det!



Mottagaren erhåller: Latitud, Longitud, Höjd, och Tid

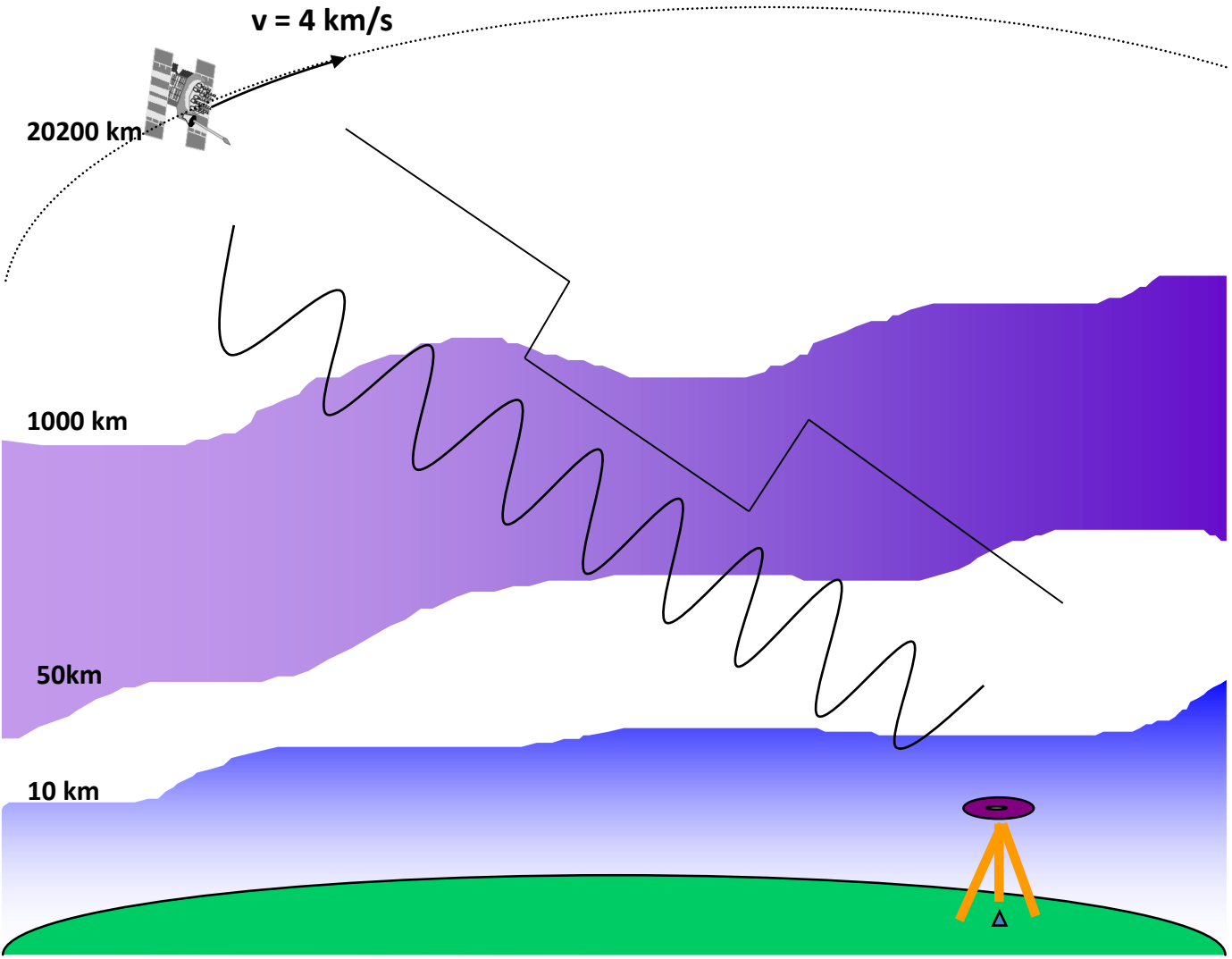


- Fel i utsända satellitbandata (~ 3-5 m)
- Fel i satelliternas klockor (< 1 m)
- Jordens atmosfär påverkar signalens utbredningshastighet (1-10 m)

Global Positioning System (GPS)

- 24 (32) satellites operated by USAF provide 24-hour, all-weather, global coverage
- Satellites are equipped with atomic clocks
- Precise time signals are broadcast on L-band radio frequencies (L1 - 1575 MHz, L2 -1227 MHz, L5 – 1176 MHz)
- Four satellite signals enable receivers to triangulate position

Signaler och felkällor



3 signaler

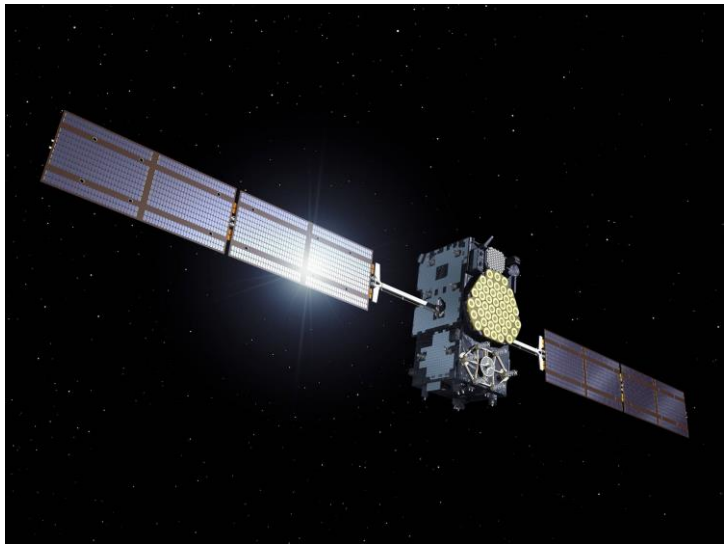
3 delar i 1 signal

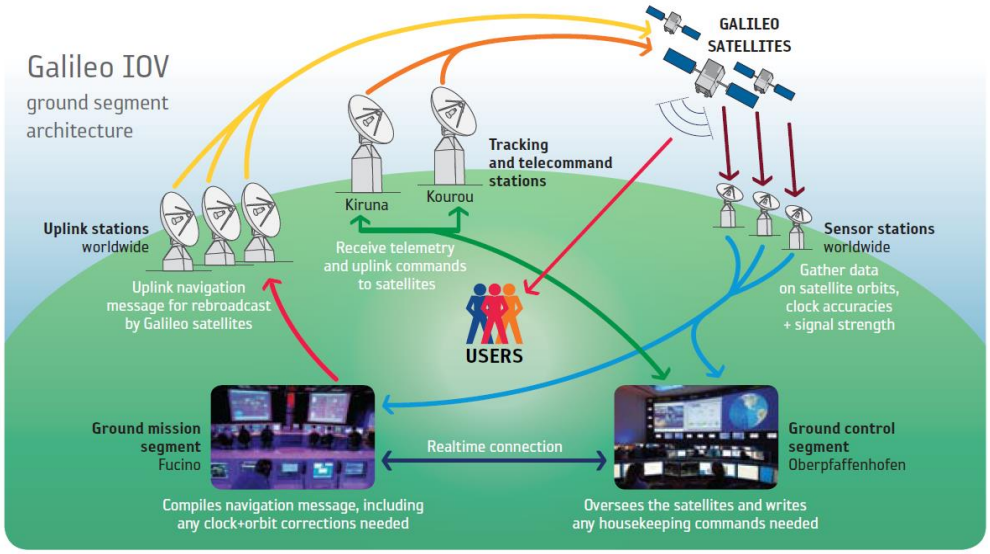
- Data - info
- ID- och mätsignal
- Bärvåg

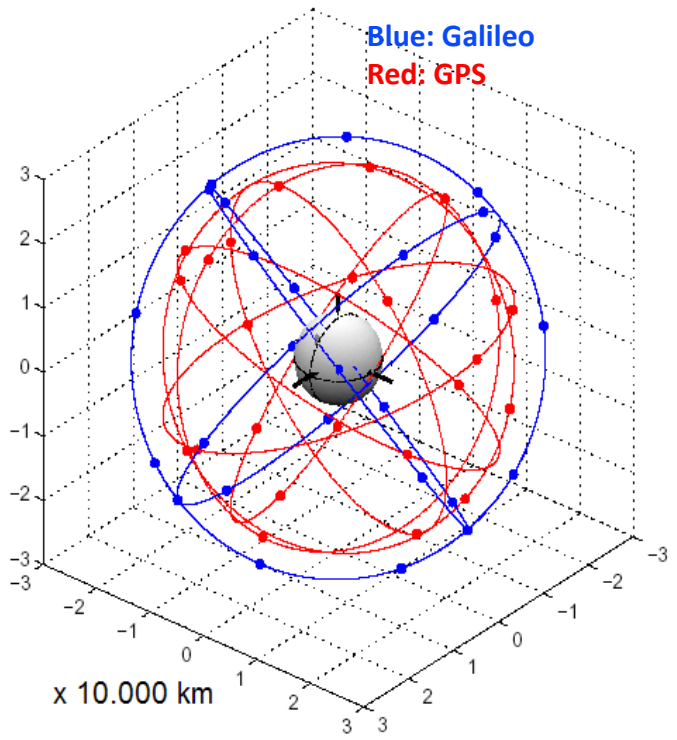
- **Felkällor**
- Satellitklockor
- Satellitbanor
- Jonosfär
- Troposfär
- Lokala effekter

Galileo Satellites

- 30 spacecrafts
- orbital altitude: 23,222 km (Medium Earth Orbit, MEO)
- 3 orbital planes, 56° inclination (9 operational satellites and one active spare per orbital plane)
- satellite lifetime: >12 years
- satellite mass: 675 kg
- satellite body dimensions: 2.7 m x 1.2 m x 1.1 m
- span of solar arrays: 18.7 m
- power of solar arrays: 1,500 W (end of life)



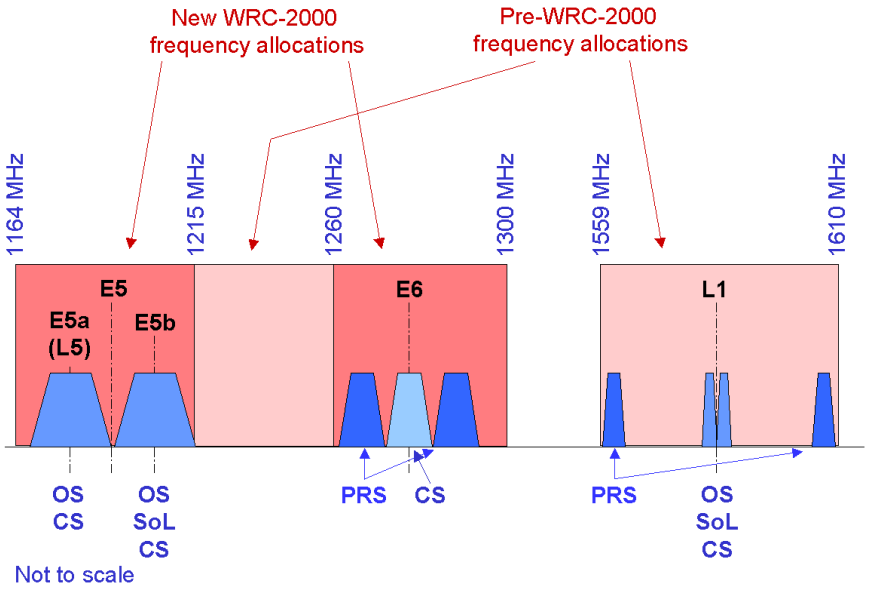




Galileo Services

There will be three different navigation services available:

- The **Open Service** (**OS**) will be free for anyone to access.
- The encrypted **Public Regulated Service** (**PRS**) is robust against jamming as needed by security authorities (police, military, etc.)
- The encrypted **Commercial Service (CS)** will be available for a fee and will offer an accuracy of better than 1 m. The CS can also be complemented by ground stations to bring the accuracy down to less than 10 cm.



Galileo Implementation Plan

Navigation solutions powered by Europe

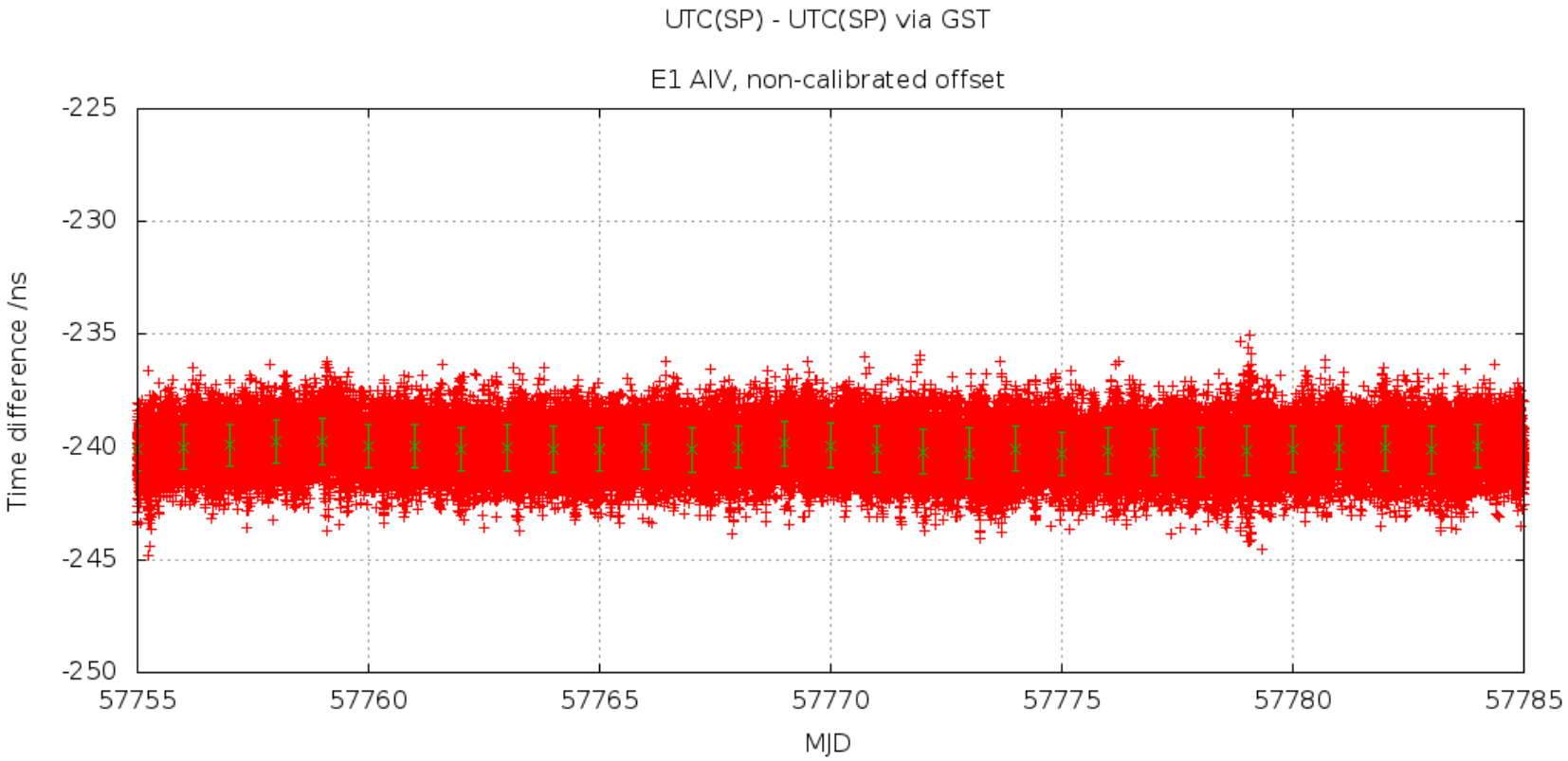
GIOVE A/B
2005 - 2011

IOV
2011 - 2012

FOC-1
2013 - 2015

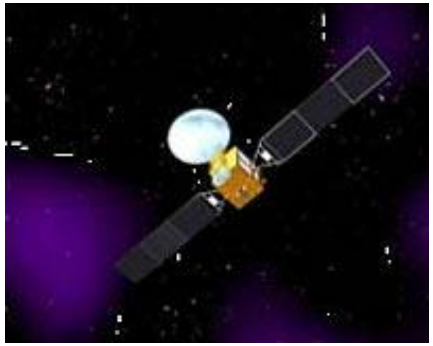
FOC-2
2018-2020

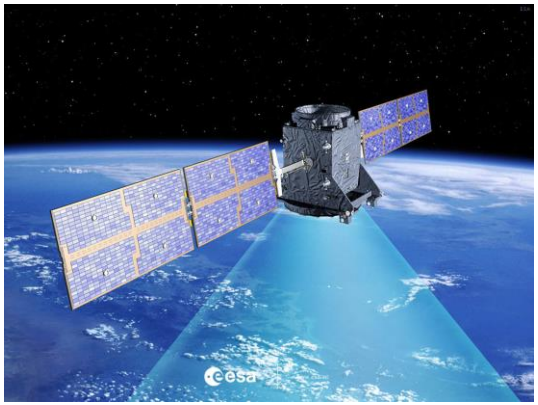
Local Short Baseline, Common Clock – Via Galileo

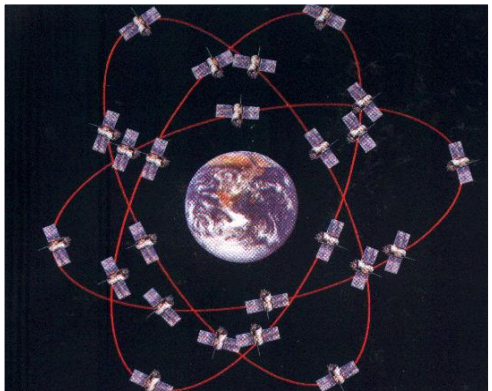


GNSS idag

- Galileo
- Beidou/Compass
- GLONASS
- Moderniserad GPS







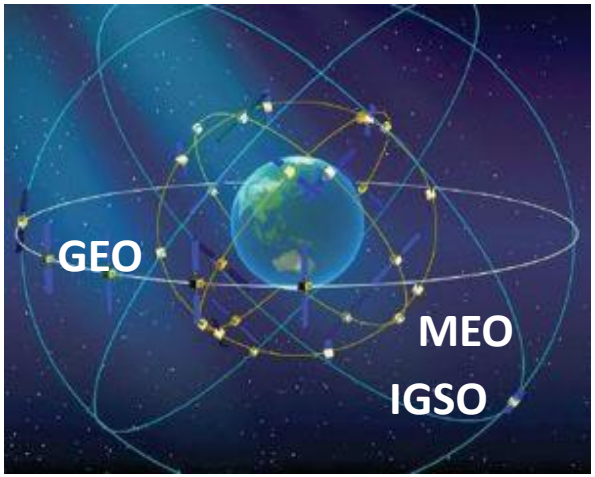
Overview, Satellite Navigation Systems

- Global Navigation Satellite Systems (GNSS)

GPS	United States	CDMA	20 200km, 12.0h	≥ 27	operational, 2014: 32 sat
GLONASS	Russia	FDMA	19 100km, 11.3h	24	operational, 2014: 29 sat
Galileo	Europe	CDMA	23 222km, 14.1h	≥ 27	in preparation, 2014: 6 sat
Compass/Beidou	China	CDMA	GEO (5) + IGSO (3) + MEO (27)	35	in preparation, 2014: 14 sat

GEO: Geostationary Earth Orbit
IGSO: Inclined Geo-Synchronous Orbit
MEO. Medium Earth Orbit

Beidou orbits



- Regional Satellite Navigation Systems

System	Country	Frequency	Orbital height & period	Number of satellites	Status
QZSS	Japan	L1, L2, and L5	HEO	4	in preparation, 2014: 1 sat
IRNSS	India	L5 and S-band	GEO (3) + IGSO (4)	7	in preparation, 2014: 1 sat

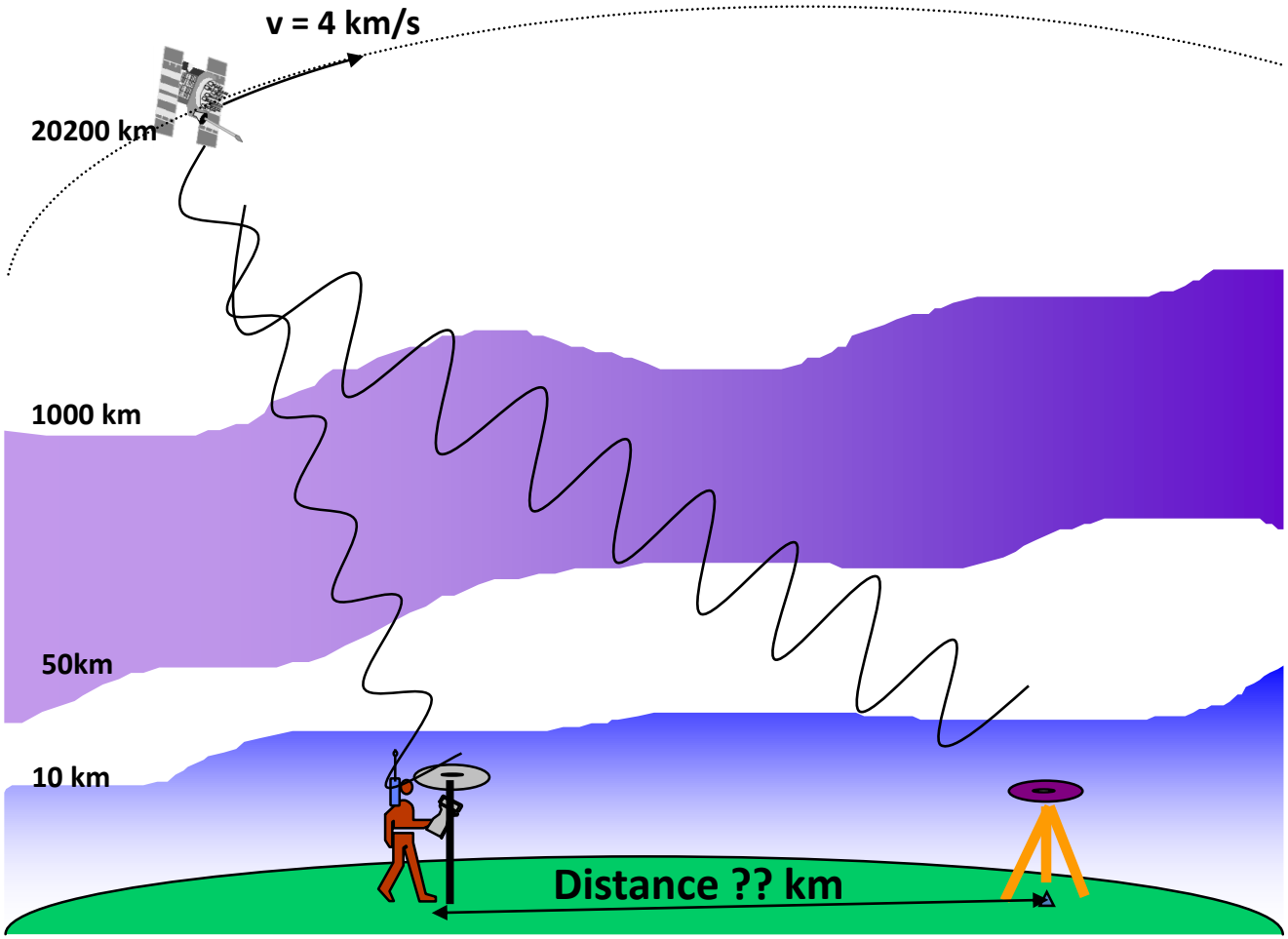
IGSO ground track

- Regional Satellite Based Augmentation Systems (SBAS):
  - WAAS(US), EGNOS (EU), MSAS (Japan) and GAGAN (India).

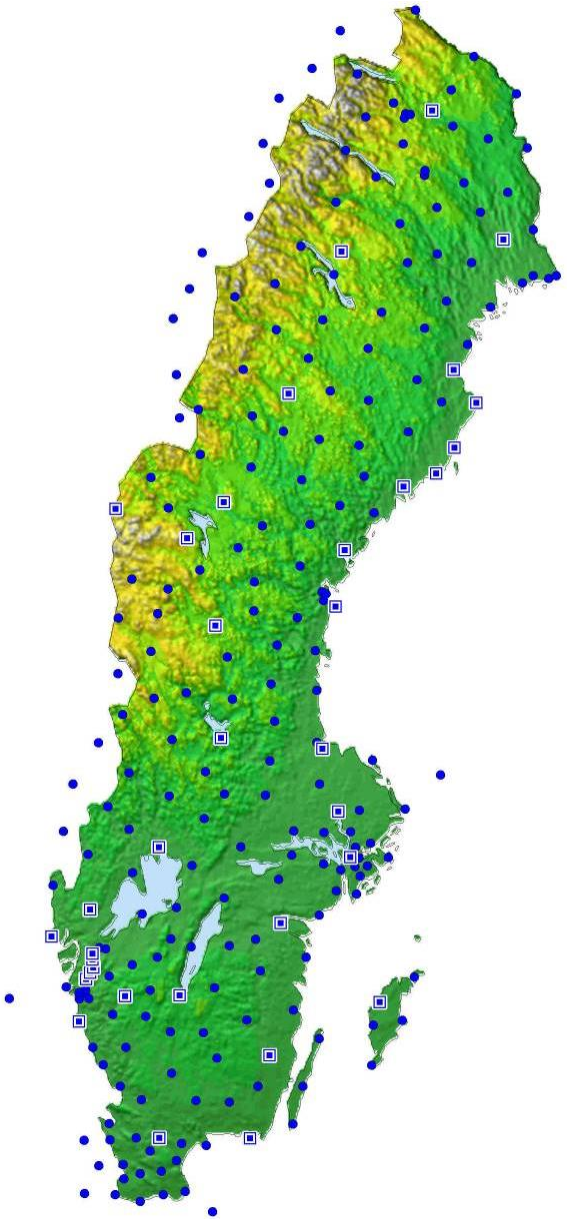
Future GNSS open signals

E5a Band	**Frequency (MHz)**	**Signal Type**
GPS L5	1176.45	BPSK(10) data and pilot
GALILEO E5a	1176.45	BPSK(10) data and pilot
GLONASS L5	1176.45	BPSK(10) data and pilot
COMPASS B2a	1176.45	BPSK(10) data and pilot
E5b Band		
GALILEO E5b	1207.14	BPSK(10) data and pilot
COMPASS B2b	1207.14	BPSK(10) data and pilot
L2 Band		
GPS L2C	1227.60	BPSK(1) data
L1 Band		
GPS L1C/A	1575.42	BPSK(1) data
GPS L1C	1575.42	BOC(1,1) data and pilot
GALILEO L1	1575.42	BOC(1,1) data and pilot
GLONASS L1	1575.42	BOC(1,1) data and pilot
COMPASS B1-C	1575.42	BOC(1,1) data and pilot

Differentiella (relativa) metoder för att eliminera gemensamma felkällor



SWEPOS Stationerna



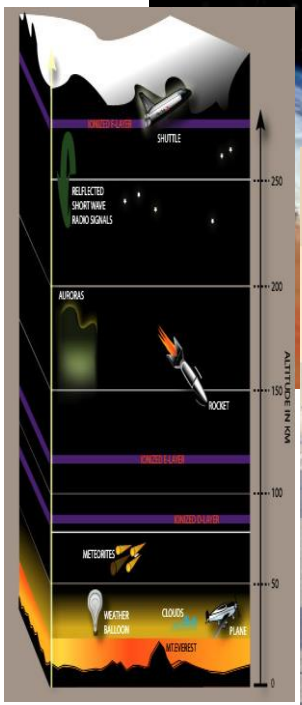
41 klass A stationer

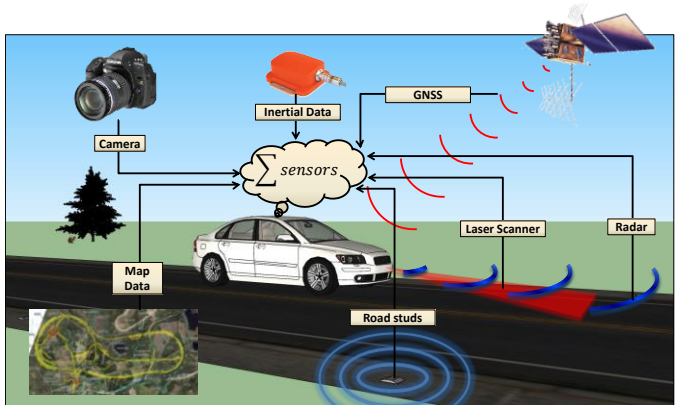
238 klass B stationer

5 IGS- och 7 EPN-stationer

Nyttan med Galileo (och övriga GNSS)

- Applikationsområden (exempel)
  - Navigation (10 m eller 3 m)
  - Positionering för anläggningsarbete 2 cm i realtid
  - Jordbruk (dm => cm i realtid)
  - Tid och frekvens för t ex telekommunikation och distribution av elkraft
  - “Sensor fusion” t ex för autonoma transporter
  - Atmosfärsövervakning – klimat och väderprognoser

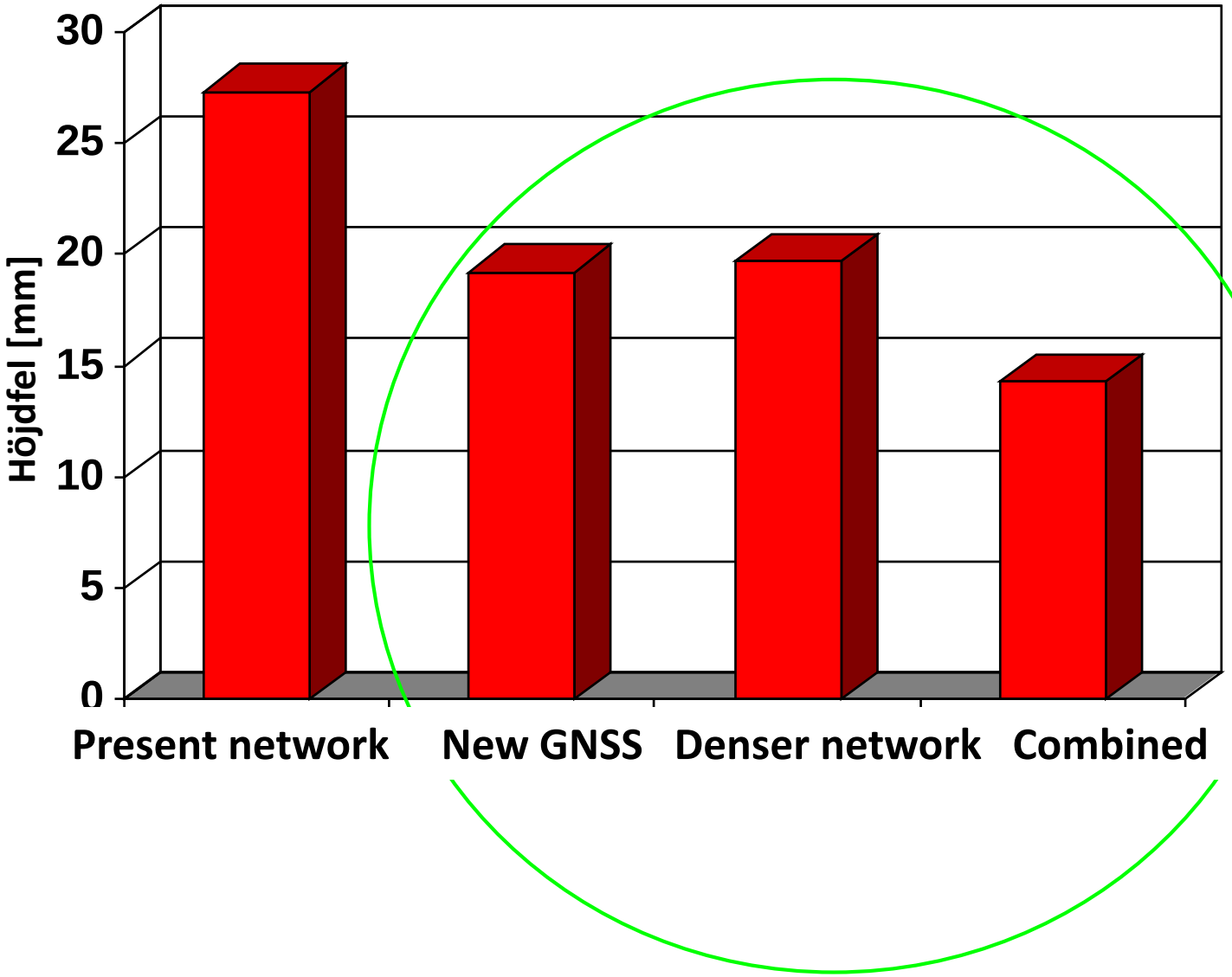


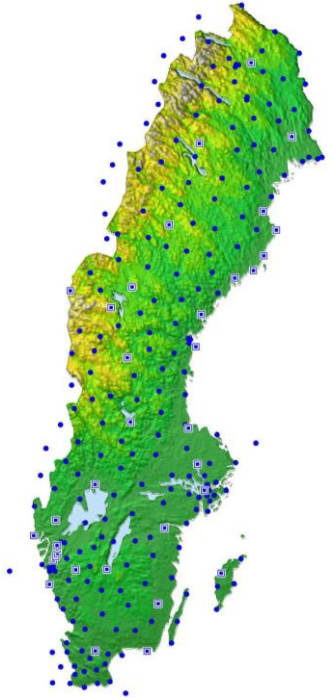


CLOSE-projekten

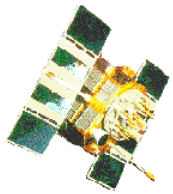
1. Förbättringar av SWEPOS-tjänsterna
2. Stationskalibrering
3. Design av nya stationer

Höjdfel i Nätverks-RTK

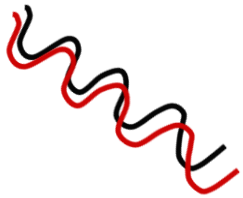




NRTK: Robustness

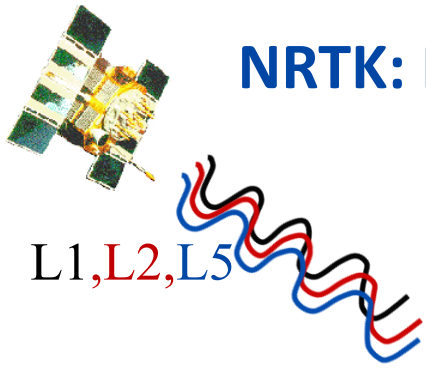


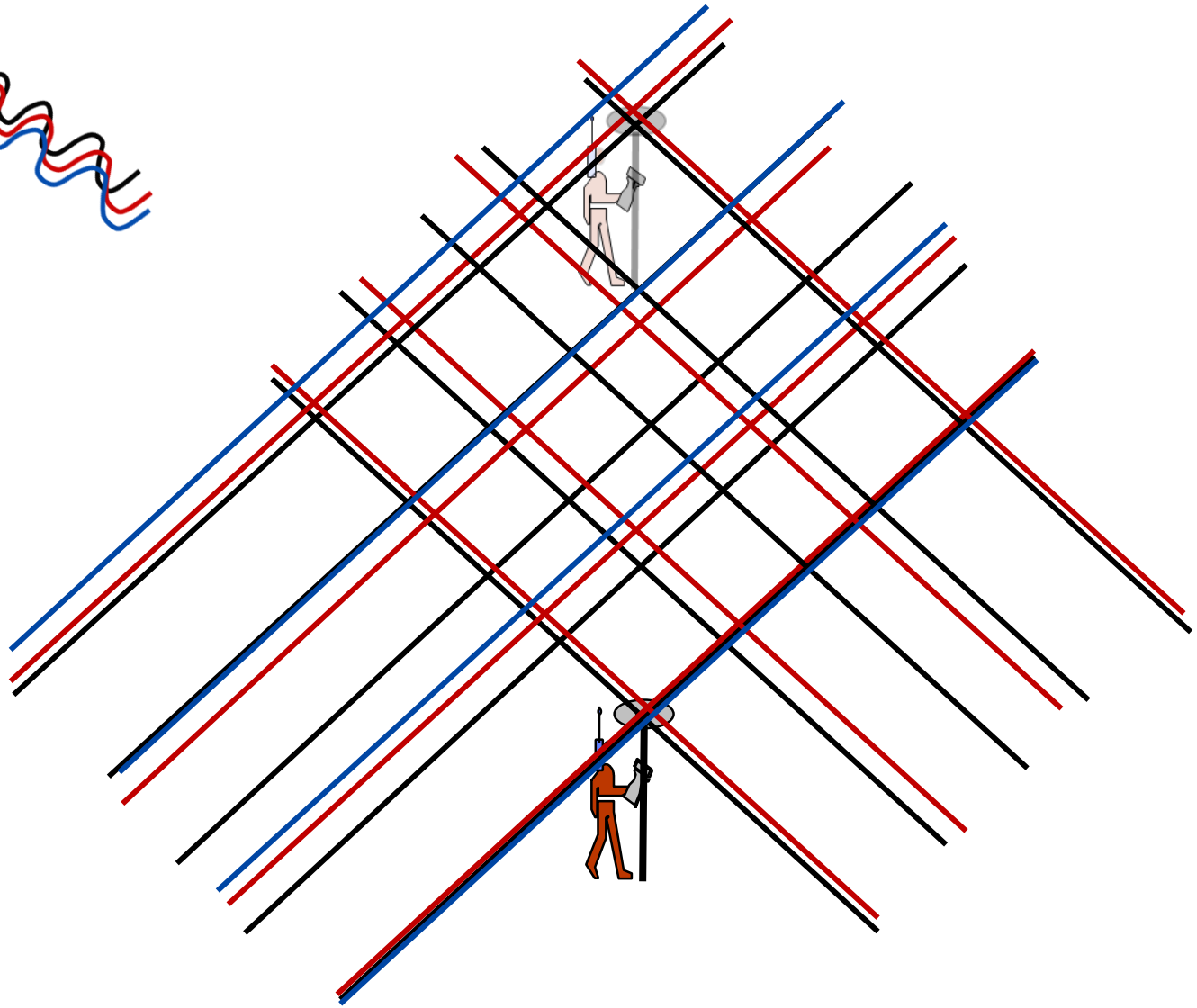
L1,L2



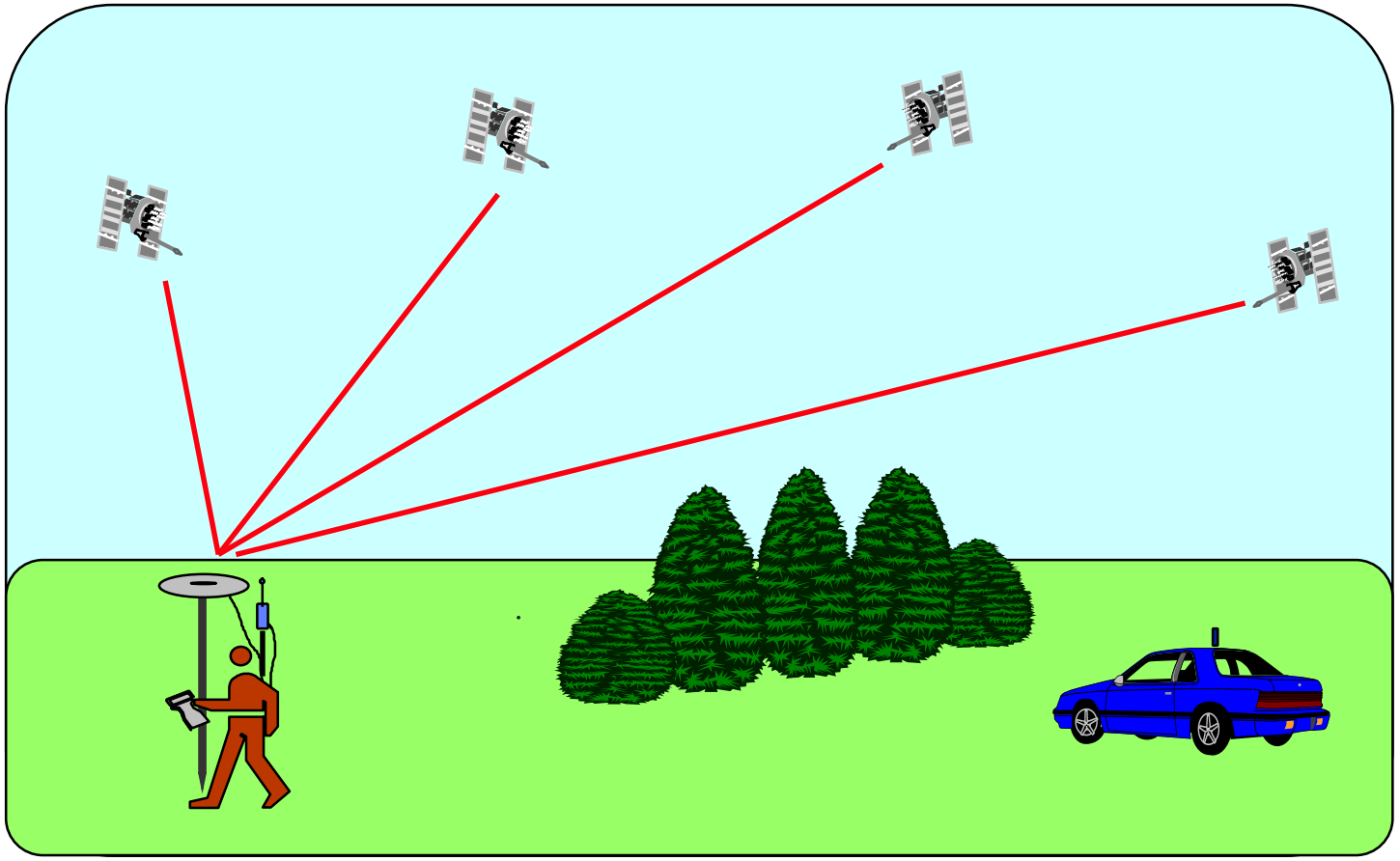
Not correct
fix

NRTK: Robustness

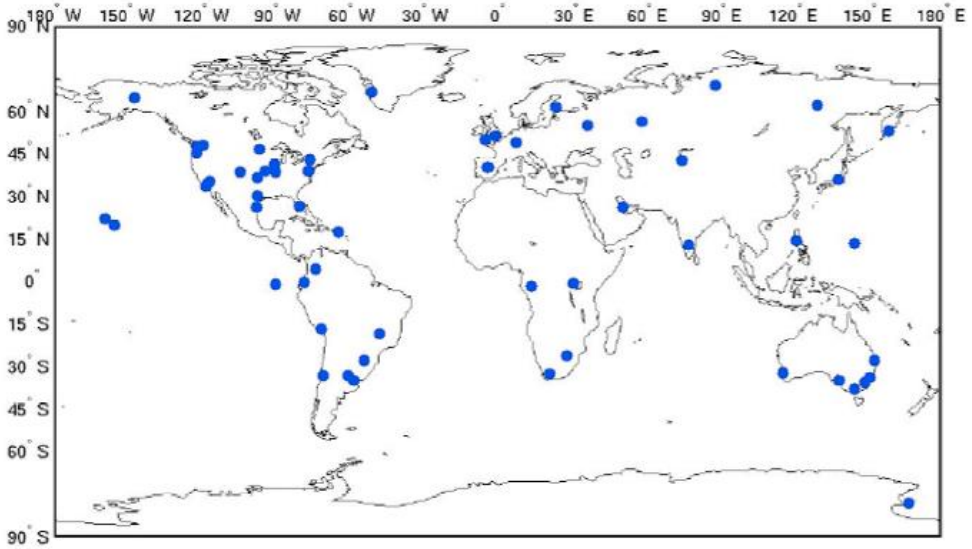




PPP – Precise Point Positioning
“Absolut” positionsbestämning på cm-nivå i realtid

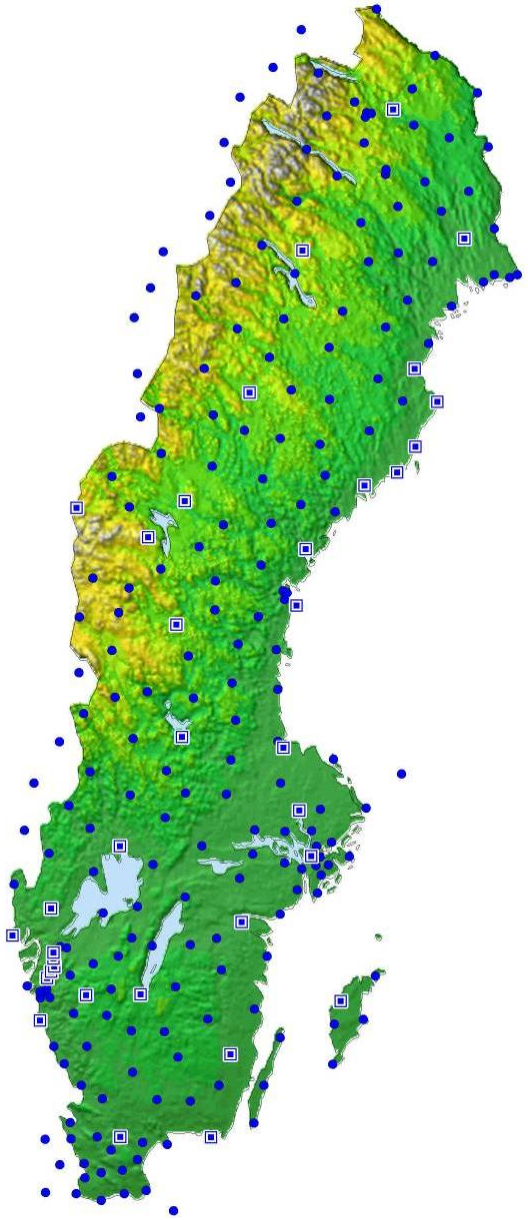


Precise Point Positioning (PPP) vs Network-RTK



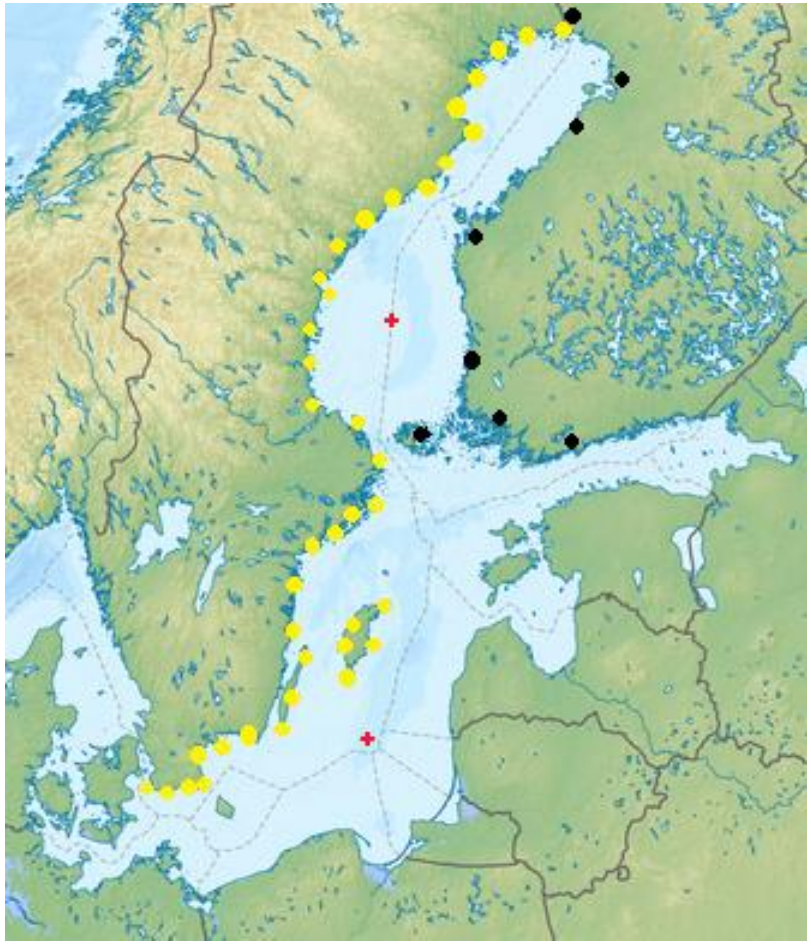
62-station combined JPL and Navcom real-time network

VS



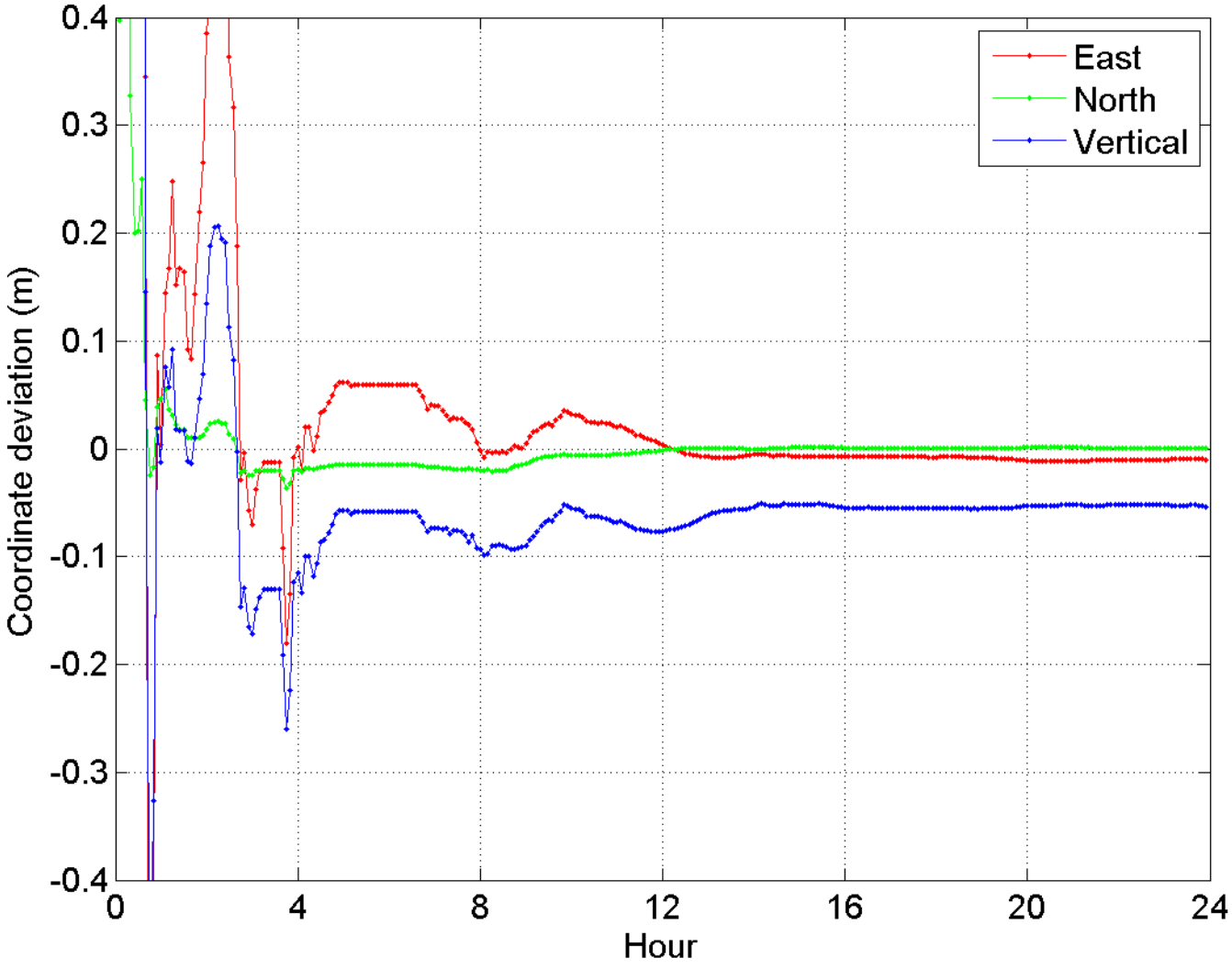
or a combination of the two => PPP-RTK

GNSS-services in the Baltic Sea

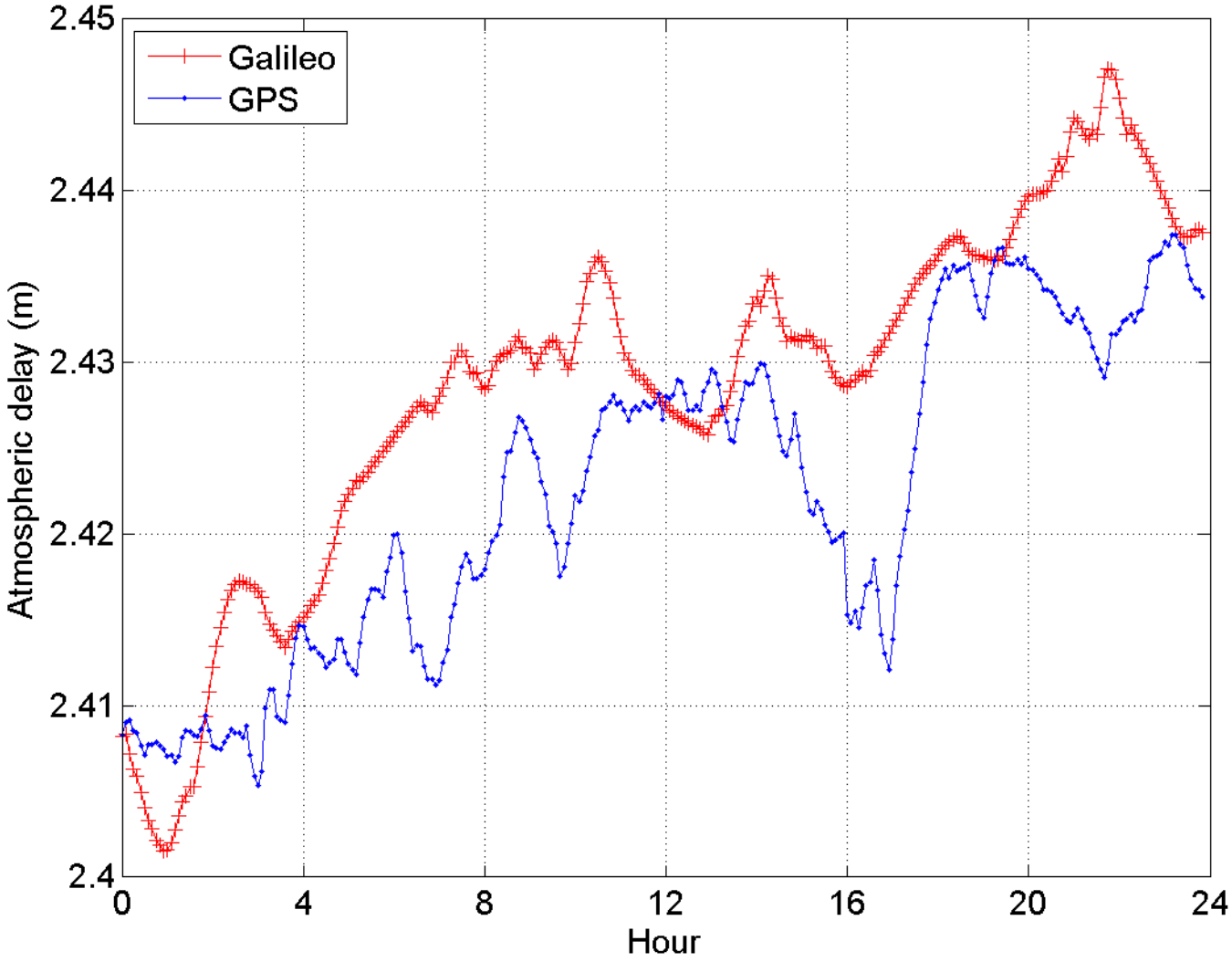


- SWEPOS and FinnRef
- New stations
- NRTK, PPP or PPP-RTK

Galileo PPP Solution

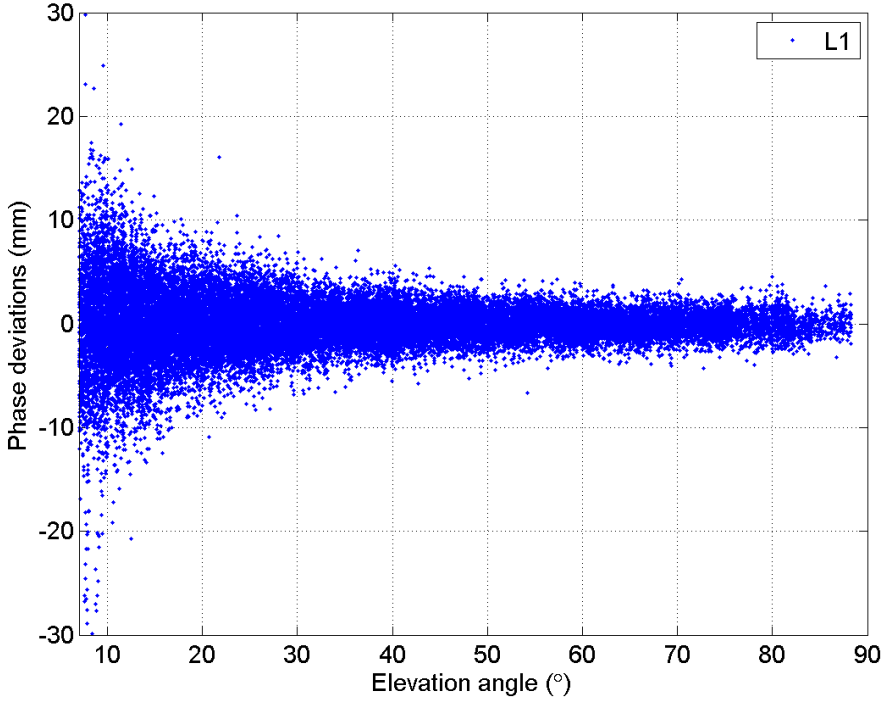


Comparison of PPP solutions: GPS vs Galileo

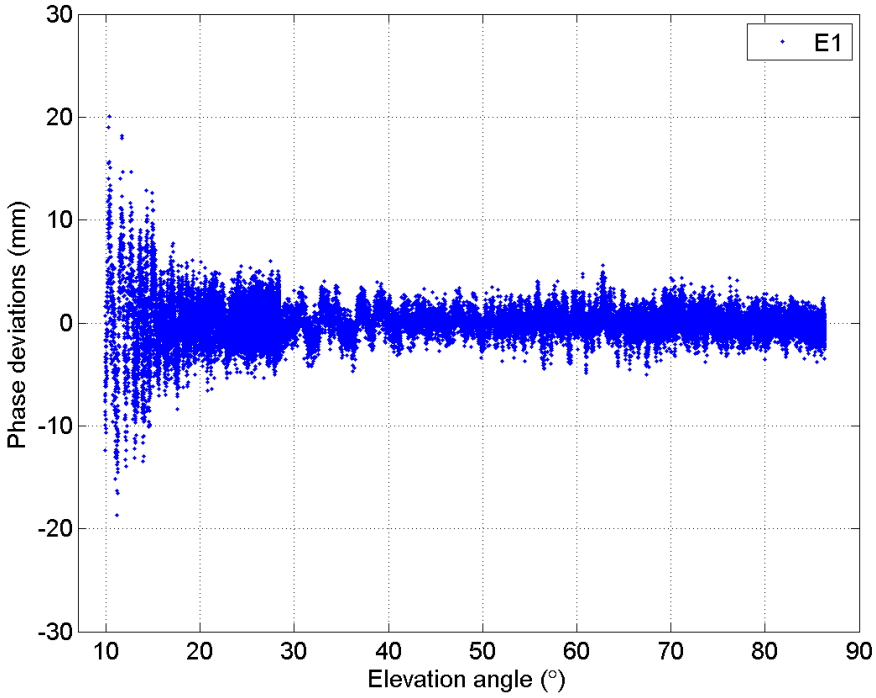


Residuals GPS L1 and Galileo E1

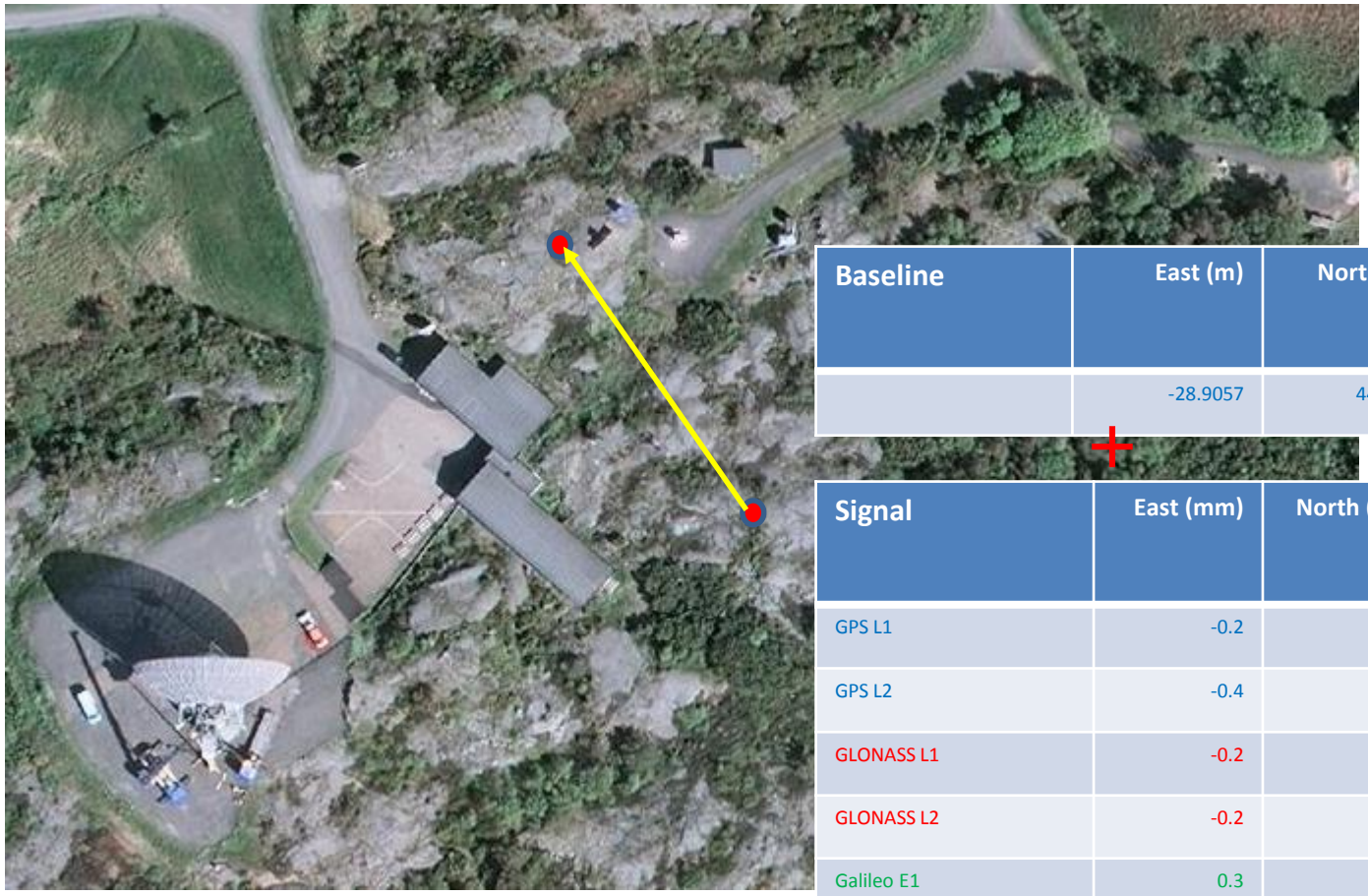
GPS



Galileo



Baseline from 3 hour data when Galileo constellation is good



Baseline	East (m)	North (m)	Up (m)
	-28.9057	44.4554	-0.5079

+

Signal	East (mm)	North (mm)	Up (mm)
GPS L1	-0.2	-0.2	0.2
GPS L2	-0.4	0.6	-0.7
GLONASS L1	-0.2	1.4	-0.1
GLONASS L2	-0.2	1.4	-0.1
Galileo E1	0.3	0.3	1.4
Galileo E5	0.0	-0.7	-0.6
Galileo E7	-0.4	0.4	-0.9