Välkomna till RNN-seminariet:

Nyhetsuppdatering från forum och projekt inom Galileo- och PNT-områdena under 2018

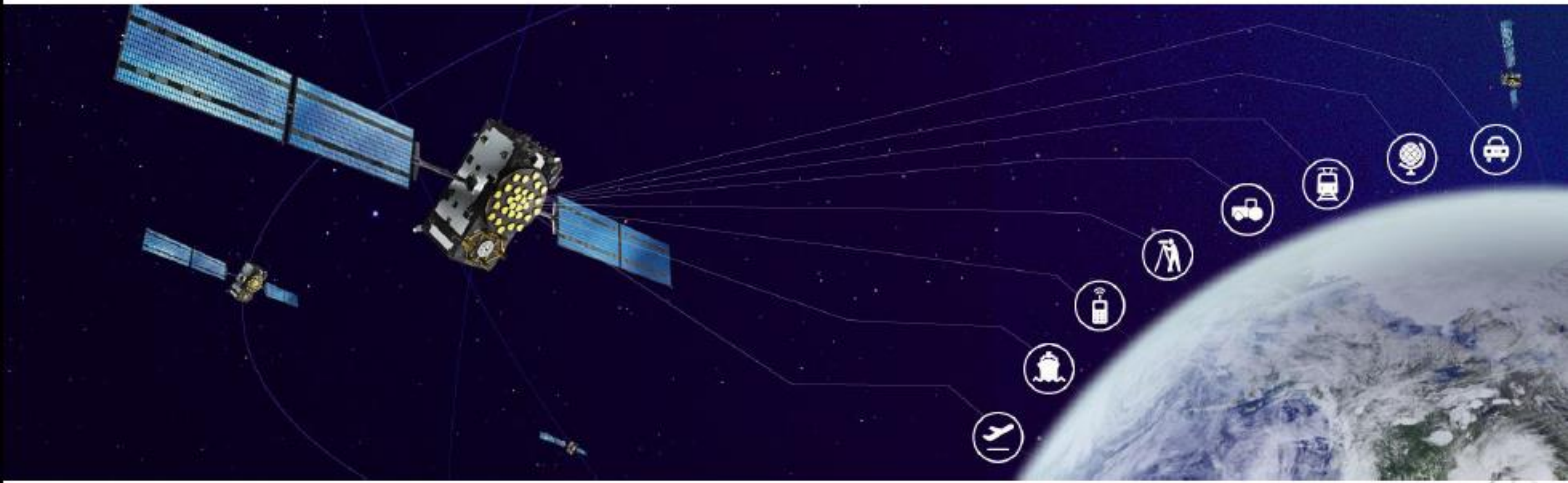
2019-03-21

8.30	Morgonfika	
9.00	Inledning	Jan Johansson, ordförande Radionavigeringsnämnden
	Galileorelaterade aktiviteter	
09.10	Nuläge för uppbyggnad och drift av Galileo och EGNOS, samt utformning/beslutsprocess för nästa generation Galileo-satelliter och nya generationen EGNOS	Christian Hånberg, Rymdstyrelsen
09.40	Förnyade testmätningar med Galileo	Lantmäteriet
09.55	Hur fungerar PPP och översikt över globala PPP-tjänster	Samieh Alissa, Lantmäteriet
10.10	Hur kan vi dra nytta av Galileo Commercial Service (CS) i Sverige	Jan Johansson
10.25	Kaffe/tepaus	
	Lägesrapporter för pågående projekt och aktiviteter inom PNT-området	
10.45	Nulägesrapport för projekten NPAD (Network-RTK for Automated Driving) och PRoPART (Precise and Robust Positioning for Automated Road Transports)	Stefan Nord, RISE (Research Institutes of Sweden)
11.05	STRIKE3 – En resumé av vad som gjorts och vad som vi har hittat	Mikael Alexandersson, FOI
11.25	A0REF – AstaZero Referenssystem för positionering	Stefan Nord
11.40	Begreppet Integritet	Samieh Alissa, Lantmäteriet
	PNT-relaterad FoU vid universitet/högskolor	
11.55	Chalmers/RISE	Jan Johansson
12.05	KTH	Milan Horemuz, KTH
12.15	Prototyp för RNNs web-sida. Kommande seminarier/konferenser inom PNT-området och aktiviteter för ökad samverkan och förbättrat informationsutbyte inom PNT-området.	Alla, diskussionsledare Jan Johansson
12.45	Avslutning	Jan Johansson

Hur kan vi dra nytta av Galileo Commercial Service (CS) i Sverige

Jan Johansson
Chalmers University of Technology
Department of Space, Earth and Environment,
Onsala Space Observatory, SE-439 42 Onsala, Sweden
jan.johansson@chalmers.se

RNN Seminar, 21 March 2019



European Global Navigation Satellite Systems Agency

Android GNSS Raw Measurements and Galileo High Accuracy Service

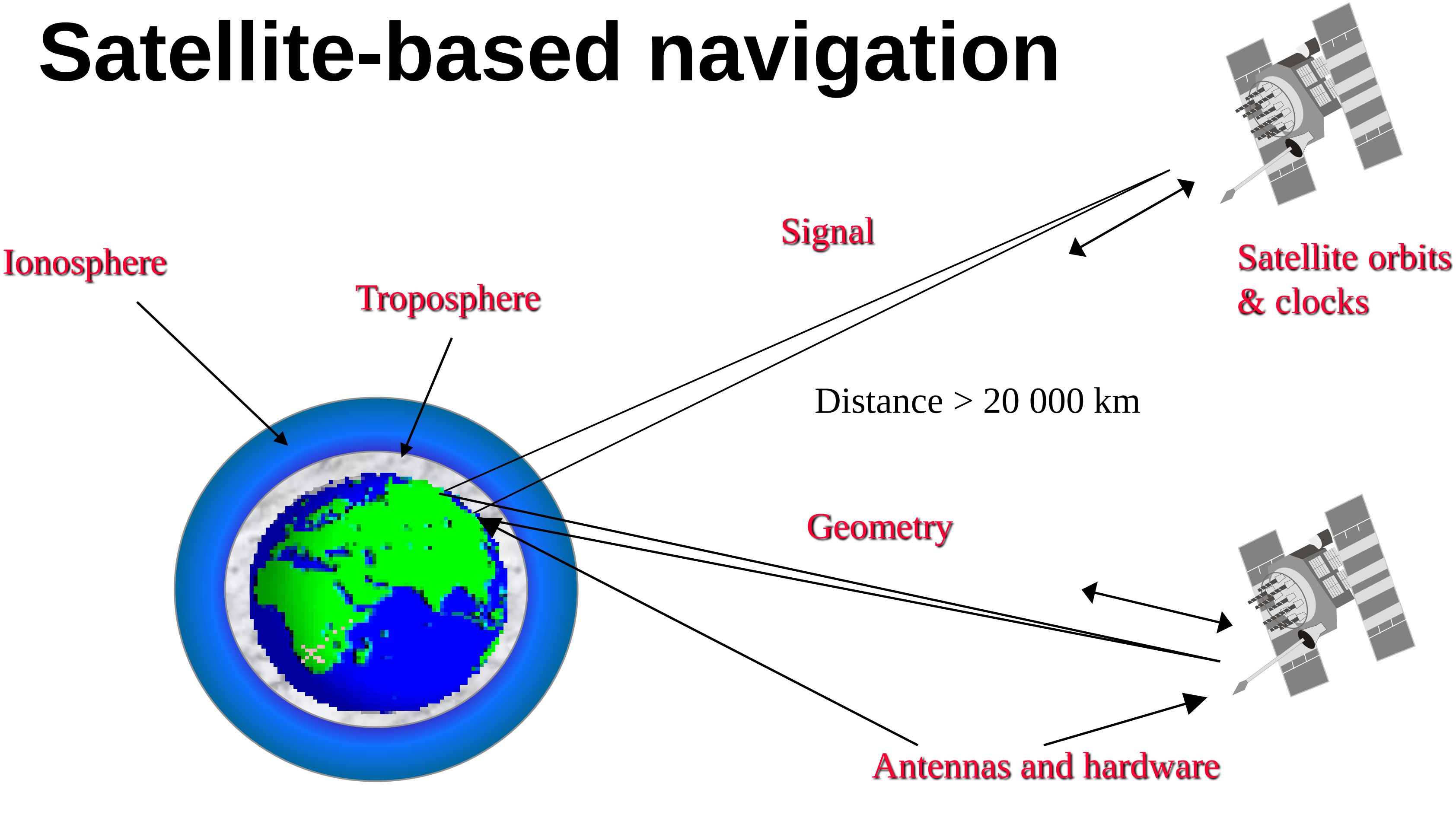
Martin Sunkevic, European GNSS Agency

29 November 2018

RNN`s New GNSS Signals seminar – opportunities for new PNT applications and improved robustness

GALILEO EGNOS
NAVIGATION SOLUTIONS POWERED BY EUROPE

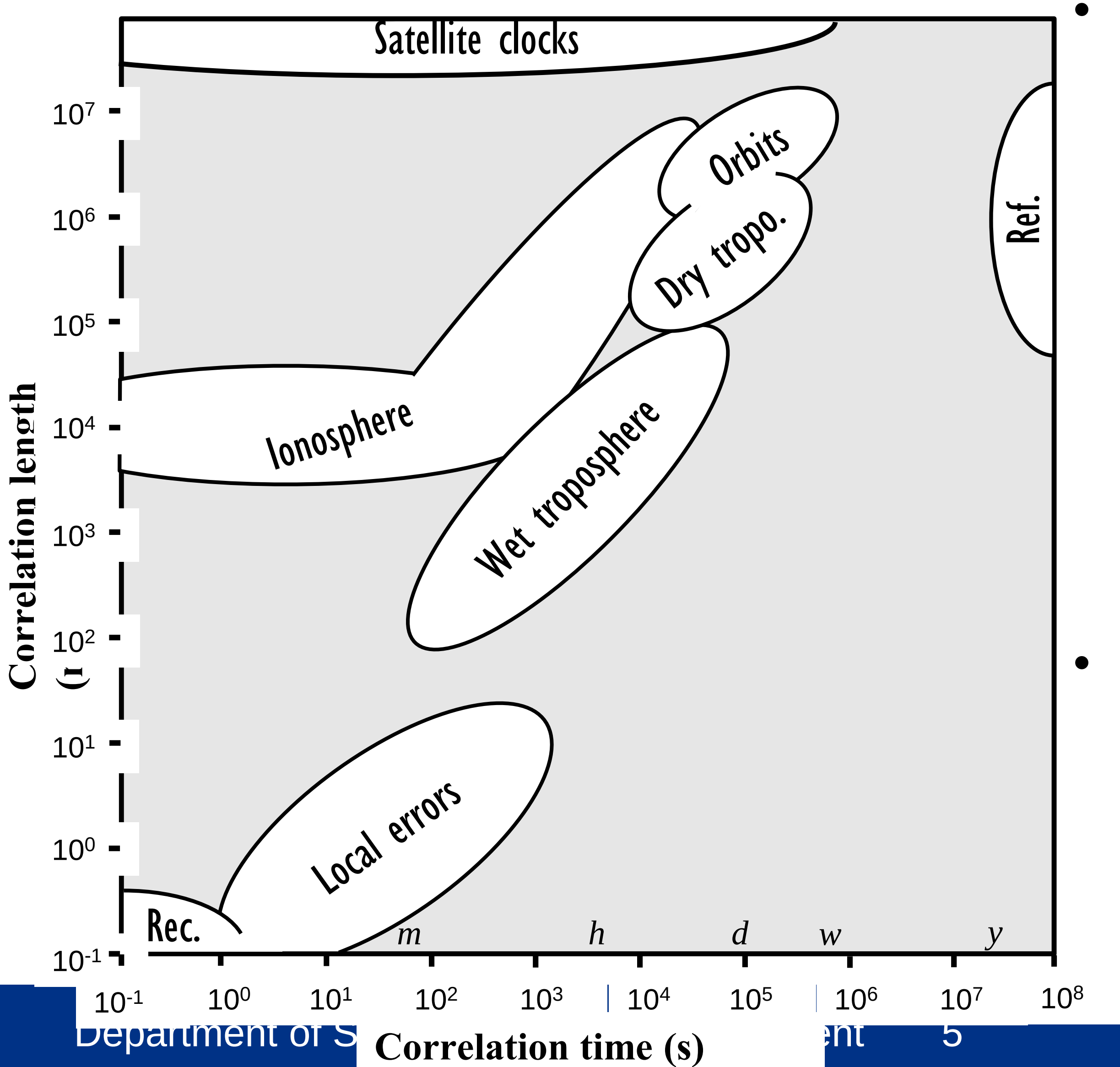
Satellite-based navigation



Received power (minimum):
$P_R = 10^{-16}$ W = - 130 dBm = - 160 dBW

Satellite power: $P_T = 27$ W
Antenna Gain: $G_T \sim 10$ dBi
Transmitted power ~ 250 W

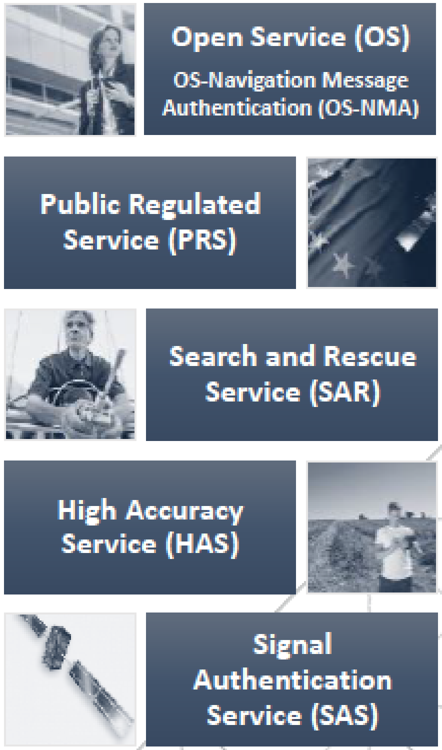
2) Perturbations



- Is it possible to make operative decisions based on our knowledge of the perturbing sources?
  - Distance to a reference indicates how error sources will affect observations
  - At what distances can we (in general terms) neglect an error source and possibly change solving strategies?
  - How long time between independent observations?
- Disclaimer:
  - Indicates the error source in space and time, not the magnitude of the error
  - For guidance only

Galileo is the European GNSS offering a wide range of services

- **Freely accessible** service for **positioning, timing** and **navigation message authentication (OS-NMA)**
- **Encrypted service** designed for **greater robustness** and **higher availability**
- Assists **locating people in distress** and **confirms** that **help is on the way**
- **Freely accessible high accuracy** positioning service
- Authentication service based on the **E6 signal code encryption**, allowing for **increased robustness of professional applications**

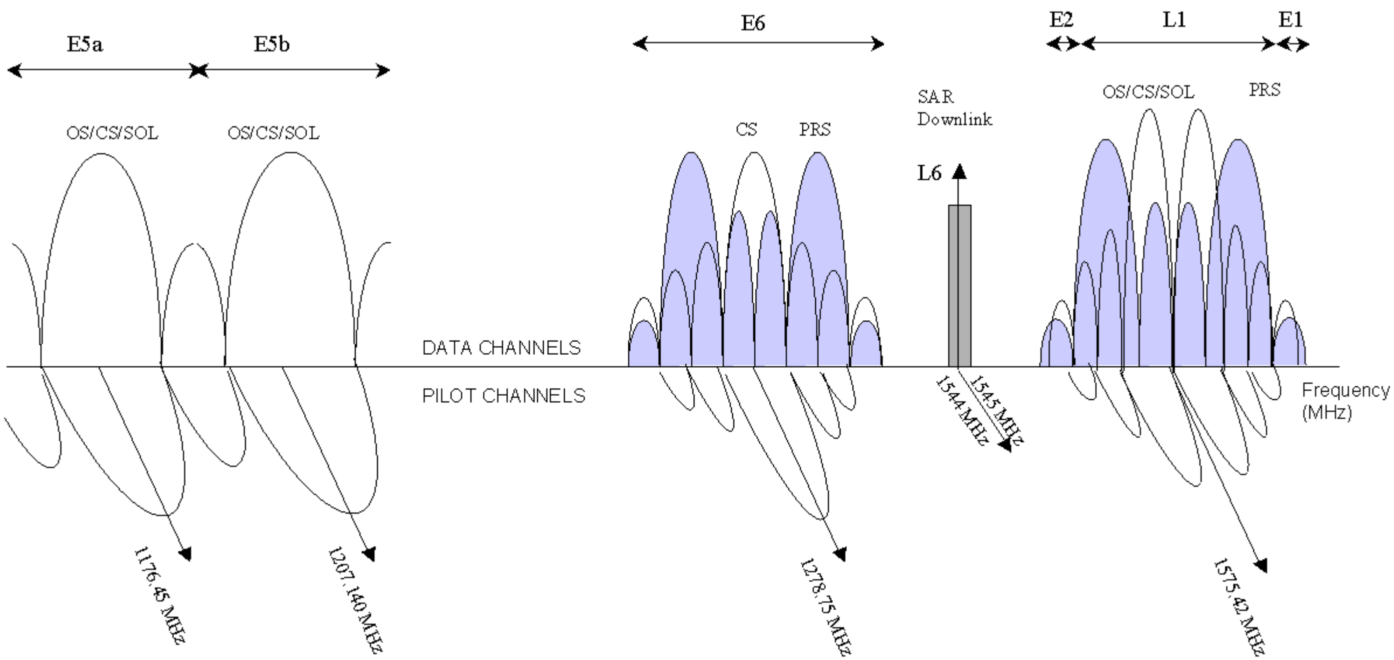


Galileo Signals

10 navigation signals are transmitted

OS : Open Service
CS: Commercial service
PRS: Public Regulated Service
~~SoL: Safety of Life~~ Descoped

Signal	Modulation	Carrier frequency (MHz)	Data /Pilot	OS	SoL	CS	PRS
E5a-I	BPSK(10)	1176.45	Data				
E5a-Q	BPSK(10)	1176.45	Pilot				
E5b-I	BPSK(10)	1207.14	Data				
E5b-Q	BPSK(10)	1207.14	Pilot				
E6-A	BOC(10,5)	1278.75	Classified				
E6-B	BPSK(5)	1278.75	Data				
E6-C	BPSK(5)	1278.75	Pilot				
L1-A	BOC(15,2.5)	1575.42	Classified				
L1-B	BOC(1,1)	1575.42	Data				
L1-C	BOC(1,1)	1575.42	Pilot				



Signal-in-Space Error + User Error => UERE

$$SISE_{GlobalAverage} = \sqrt{0.9673 \cdot R^2 + CLK^2 + 0.01632 \cdot (A^2 + C^2) + 1.967 \cdot CLK \cdot R}$$

$$UERE = \sqrt{SISE^2 + UEE^2}$$

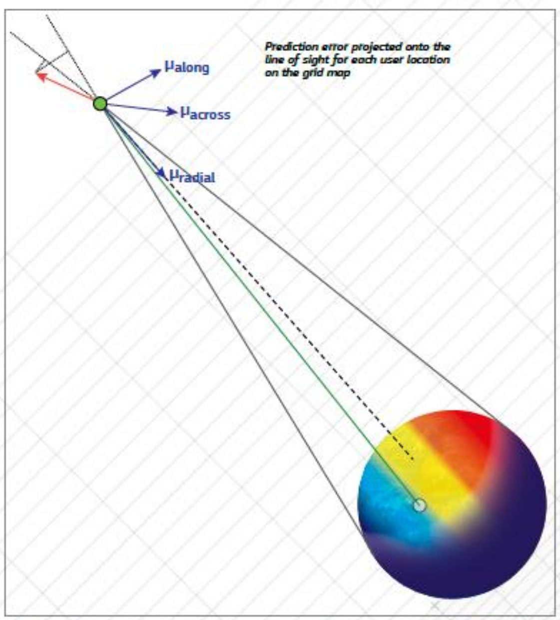
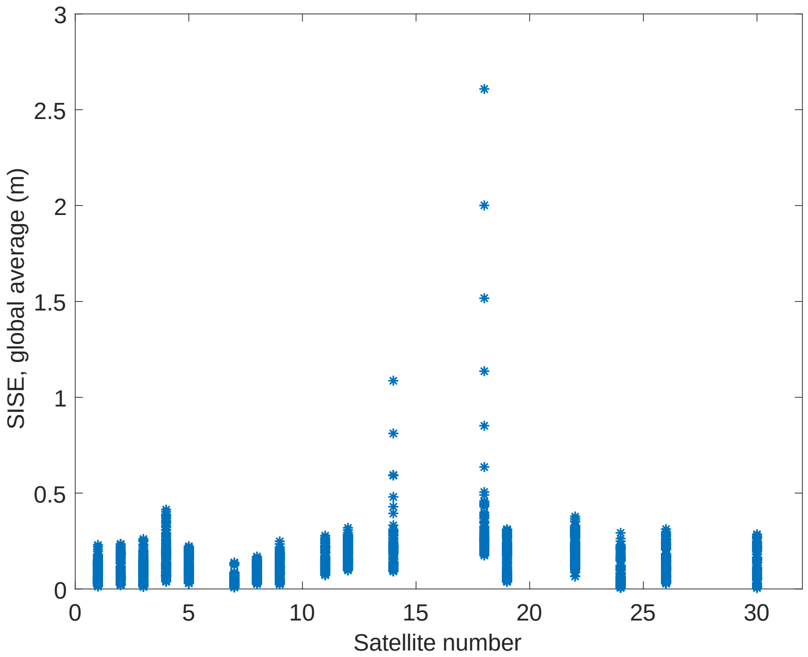


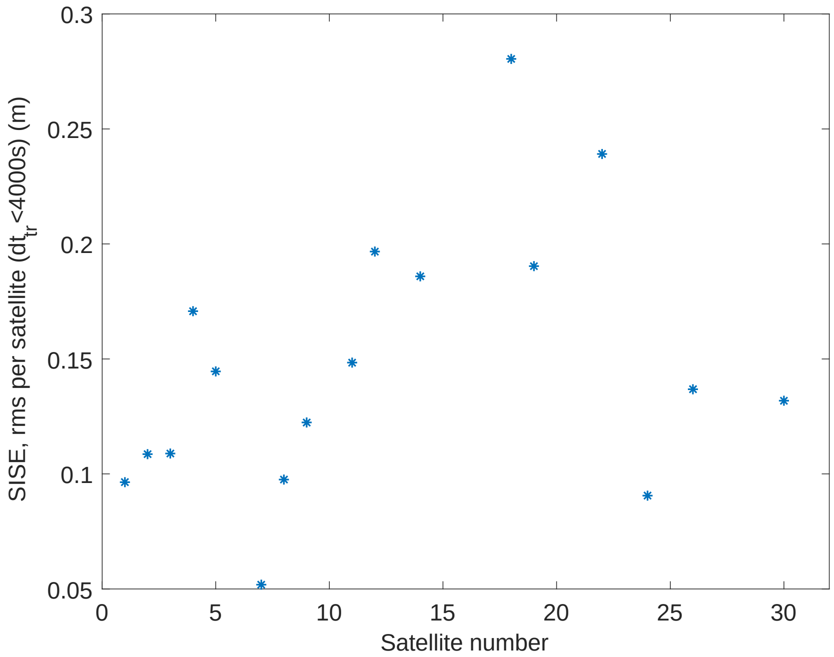
Figure 6. SISE projection onto the line of sight for each user location

ERROR SOURCE	[METERS]
Signal In Space Ranging Error (SISE)	0.67
Residual Ionosphere error	6 (5°) -3 (90°)
Residual Troposphere error	1.35 (5°) – 0.14 (90°)
Thermal noise, Interfer, Multipath	0.35 (5°) – 0.23 (90°)
Multipath bias error	0.59
Satellite BGD error	0.30
Code-Carrier Ionospheric divergence error	0.30
Total (1-sigma error [cm])	6.26 (5°) – 3.10 (90°)

Table 23. Single Frequency E1 – Rural Pedestrian (RP) User Environment (*)

SISE Global Average for each Satellite





UERE Calculations – E1 and E1/E5a

ERROR SOURCE	[METERS]
Signal In Space Ranging Error (SISE)	0.67
Residual Ionosphere error	6 (5°) -3 (90°)
Residual Troposphere error	1.35 (5°) – 0.14 (90°)
Thermal noise, Interfer, Multipath	0.35 (5°) – 0.23 (90°)
Multipath bias error	0.59
Satellite BGD error	0.30
Code-Carrier Ionospheric divergence error	0.30
Total (1-sigma error [cm])	6.26 (5°) – 3.10 (90°)

Table 23. Single Frequency E1 – Rural Pedestrian (RP) User Environment (*)

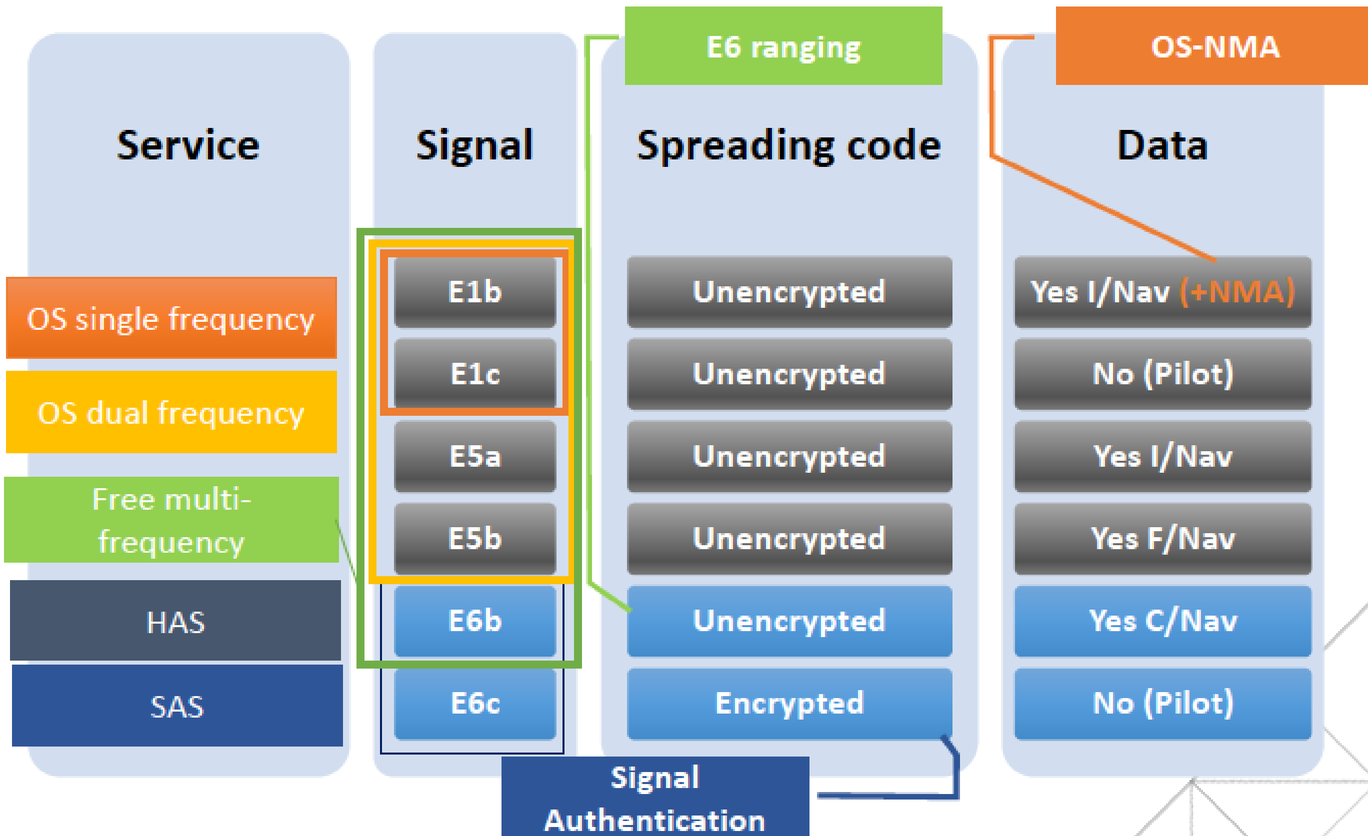
ERROR SOURCE	[METERS]
Signal In Space Ranging Error (SISE)	0.67
Residual Ionosphere error	0.08 (5°) - 0.03 (90°)
Residual Troposphere error	1.35 (5°) – 0.14 (90°)
Thermal noise, Interfer, Multipath	0.46 (5°) – 0.13 (90°)
Multipath bias error	0.19
Satellite BGD error	0.0
Code-Carrier Ionospheric divergence error	0.0
Total (1-sigma error [cm])	1.59 (5°) – 0.72 (90°)

Table 24. Dual Frequency E1-E5a – Rural Vehicle (RP) User Environment (*)

Commercial Service goes for FREE

- As per EU GNSS regulation, **Galileo foresees a Commercial Service (CS) offered for a fee for professional apps**
- **In early 2017**, the EU adopted a **Decision** (Implementing Decision 2017/224) **defining the fee-based CS as High Accuracy Service (CS-HA) and Authentication.** CS-HA was foreseen to be based on commercial, proprietary format, not under Galileo's responsibility
- However, **new circumstances taken into account**: high accuracy broadening towards the mass market and being offered for free already by satnav providers and other public entities.
- Re-assessment process has culminated in an amendment to the Decision (Implementing Decision 2018/321), to redefine the High Accuracy service and **provide it for free.**

Overview of signals
Open service / High Accuracy Service / E6 ranging



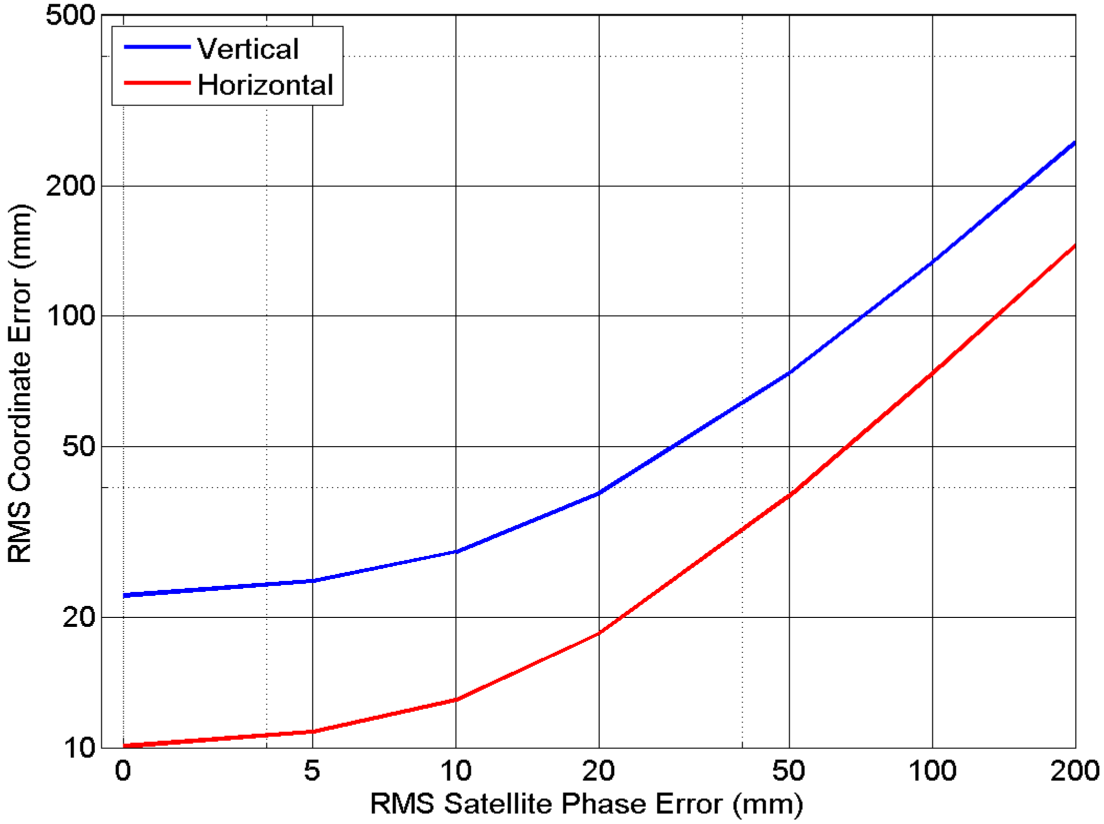
HAS will be offered for free and using standard format

GSA

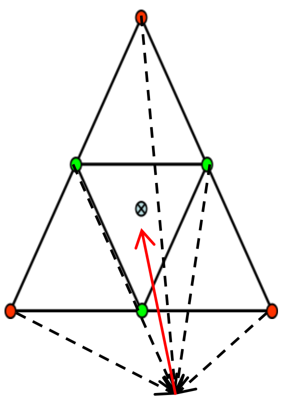
- High accuracy (PPP) corrections provided in the Galileo E6-B signal component (= no need for additional communication channel):
  - **Satellite orbits**
  - **Satellite clock corrections**
  - **Code biases for multi-frequency**
  - **Signal/correction quality information**
  - Phase biases (TBC)
  - Ionosphere in EU (to be confirmed)
- Corrections will be disseminated for (**E1, E5a, E5b, E6b, E5**(TBC)) and GPS (L1, L2, others TBC), and in the future potentially for other GNSS
- Global coverage when fully operational, partial coverage before (EU will be always included)
- HAS data transmitted **for free**, based on (used as a starting point) **open standard format RTCM CSSR** (currently under definition)
- "target horizontal user **error around two decimetres**", depending not only on user receiver, algorithm and environment (currently under definition)
- HAS distribution via terrestrial network (under consideration)

	Signal and Data features
Frequency	1278.75 MHz
Signal	E6B
Min. Power	-158 dBW
Modulation	BPSK(5)
Chip Rate	5.115 Mcps
Code Length	1 ms
Symbol Rate	1000 sps
Data Rate	492 bps
HA Data Rate	448 bps (TBC)
Data Coding	FEC, as per Galileo OS SIS ICD, + interleaving 123 x 8
Spreading Code Encryption	No
Data Format	TBD, but based on an open ICD.
Data (TBC)	Orbit and clock corrections, code and phase biases, SQM, flags, ionospheric information.

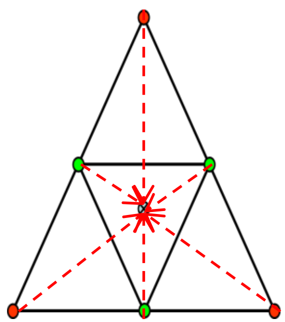
Simulations of the PPP performance in terms of the horizontal (red) and vertical (blue) coordinate error as a function of the quality of the observables.



Nätverks-RTK

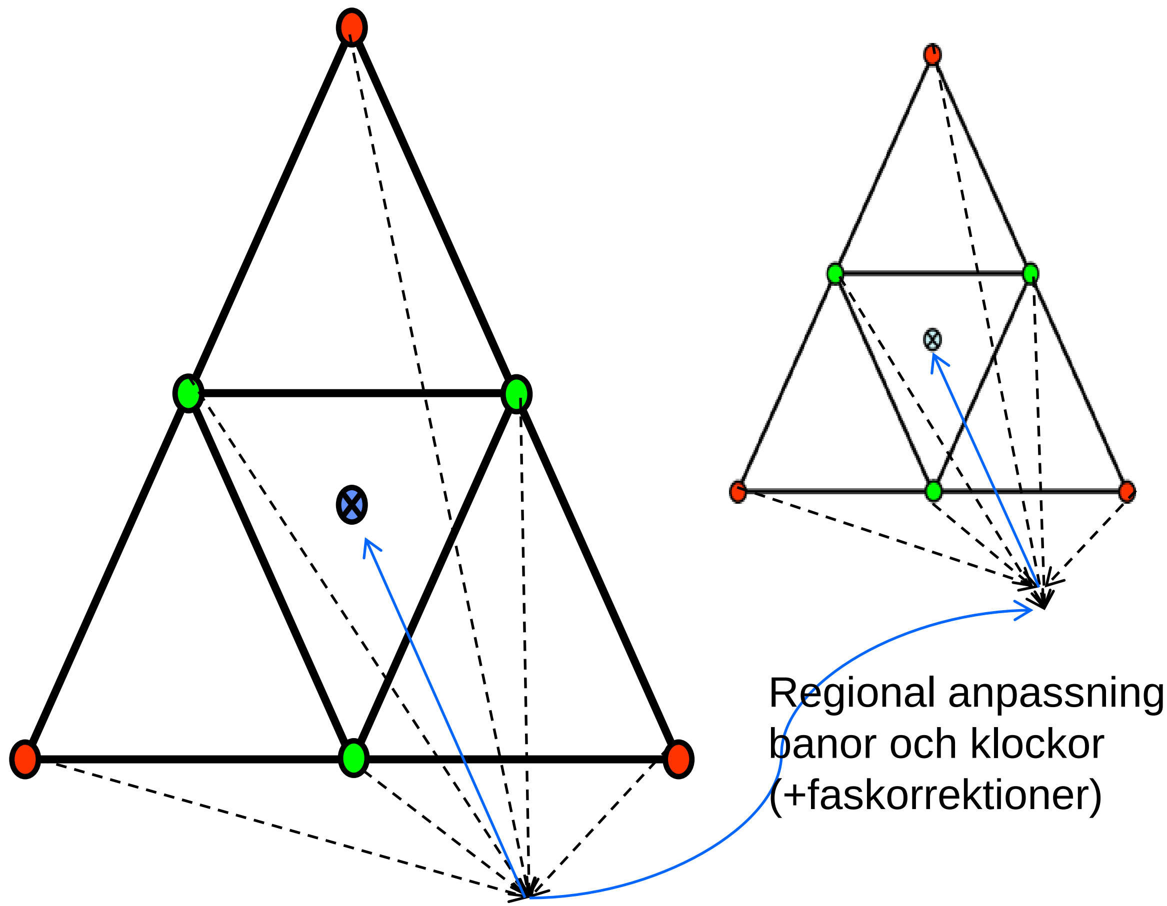


Virtual Reference Station (VRS)



Master-Auxiliary Concept (MAC)

PPP   Hybrid: PPP-RTK



Global bestämning av satelliters banor och klockor

GNSS Applications (High-precision)

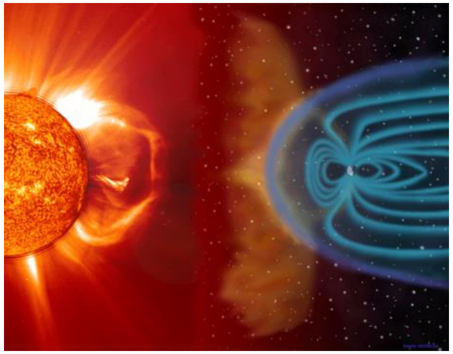
Full GNSS signal package => codes and carriers

Real-time positioning and navigation

- Surveying, Machine guidance, Agriculture
- Space missions, Remote sensing

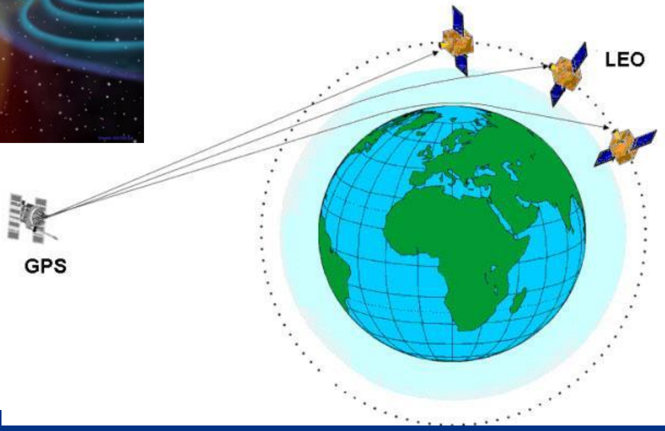
Time and frequency

- Communication networks
- Electrical power grids



Atmospheric remote sensing

- Ionosphere TEC, Troposphere



Monitoring, Geodesy and Geophysics

- Important infrastructure e.g. bridges
- Tectonic plate motion, Sea level

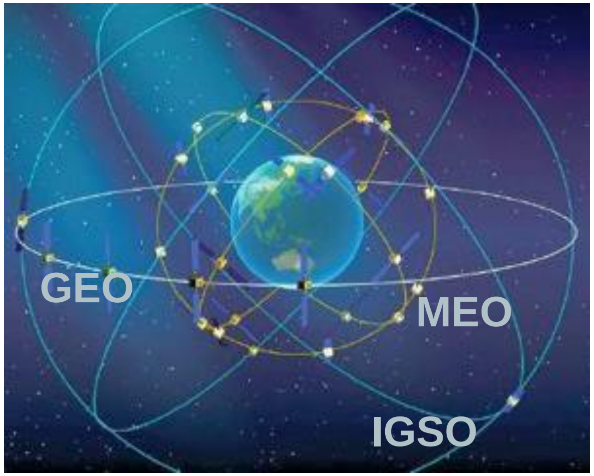
Interoperability with other GNSS

- 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).