GNSS PPP (Precise Point Positioning)

A New Development for High Precision Navigation and Positioning

John Vint, Survey Manager, Fugro Survey AS

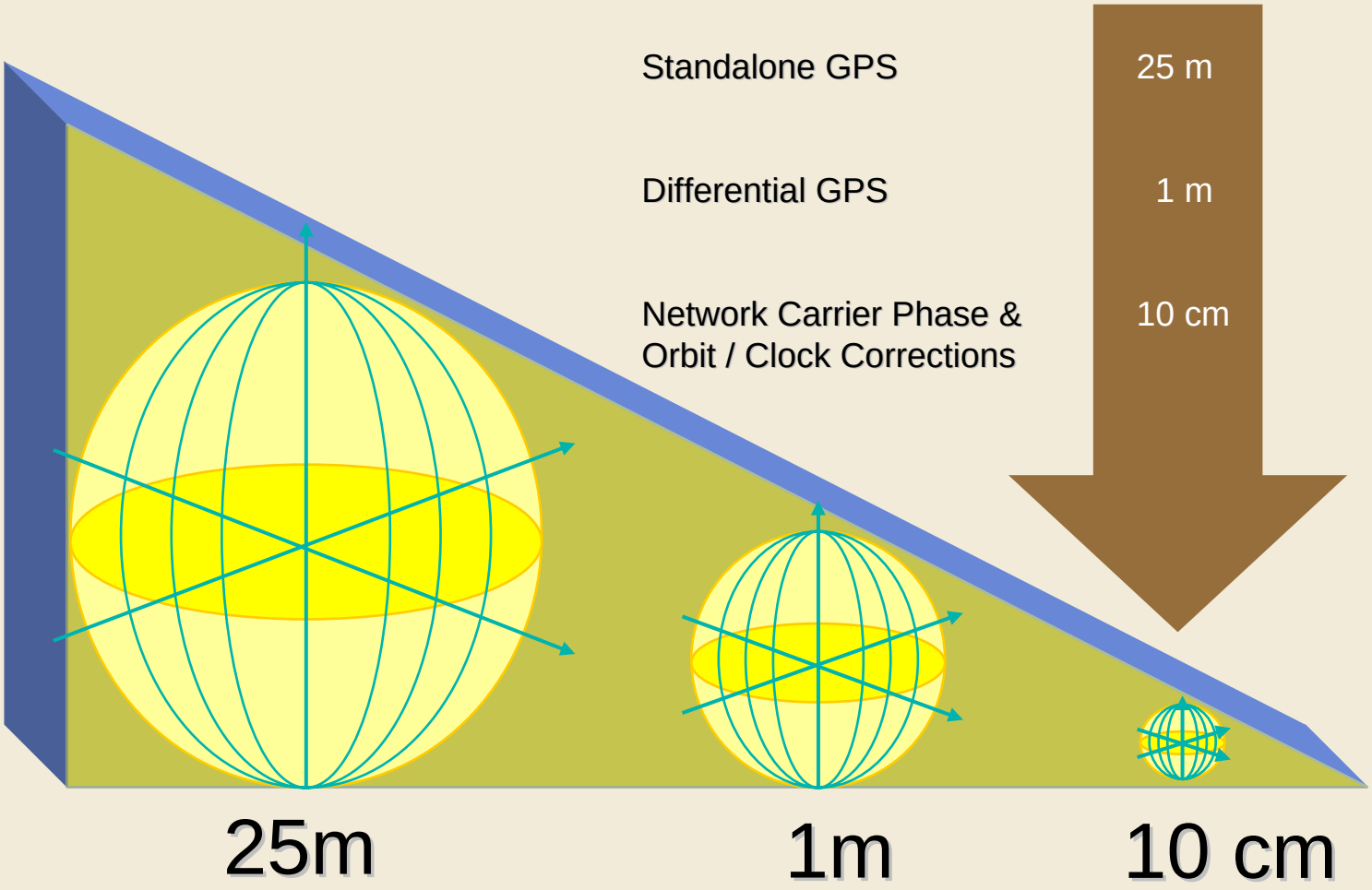
NNF – E-Nav Conference, Bergen, 6 March 2009

Scope of Presentation

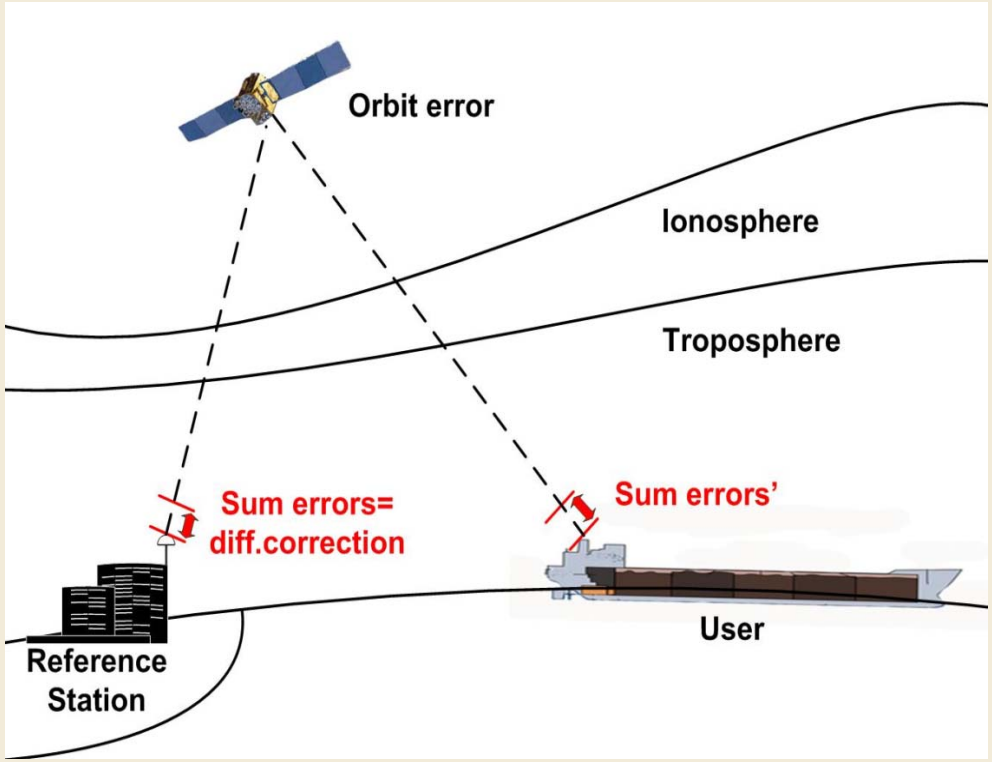
- What is GNSS PPP ?
- GPS Based High Precision Systems.
- Return of GLONASS.
- Fugro G2 Development.
- Advantages of Combined GNSS Systems.
- Products, Trials and Results.
- What does the Future have in store ?

GNSS (Global Navigation Satellite Systems)

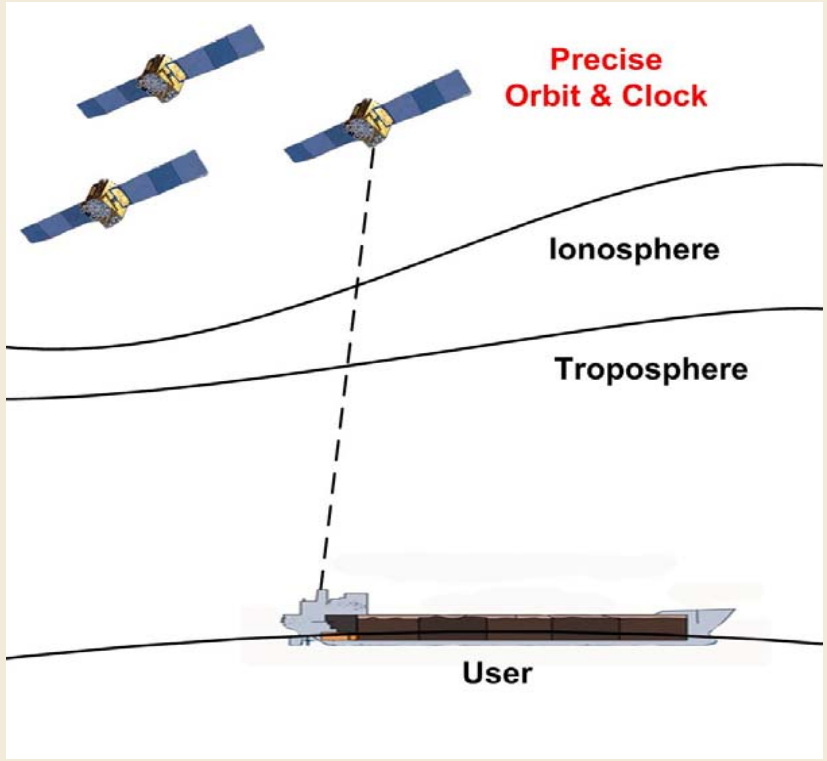
GPS Positioning Accuracies



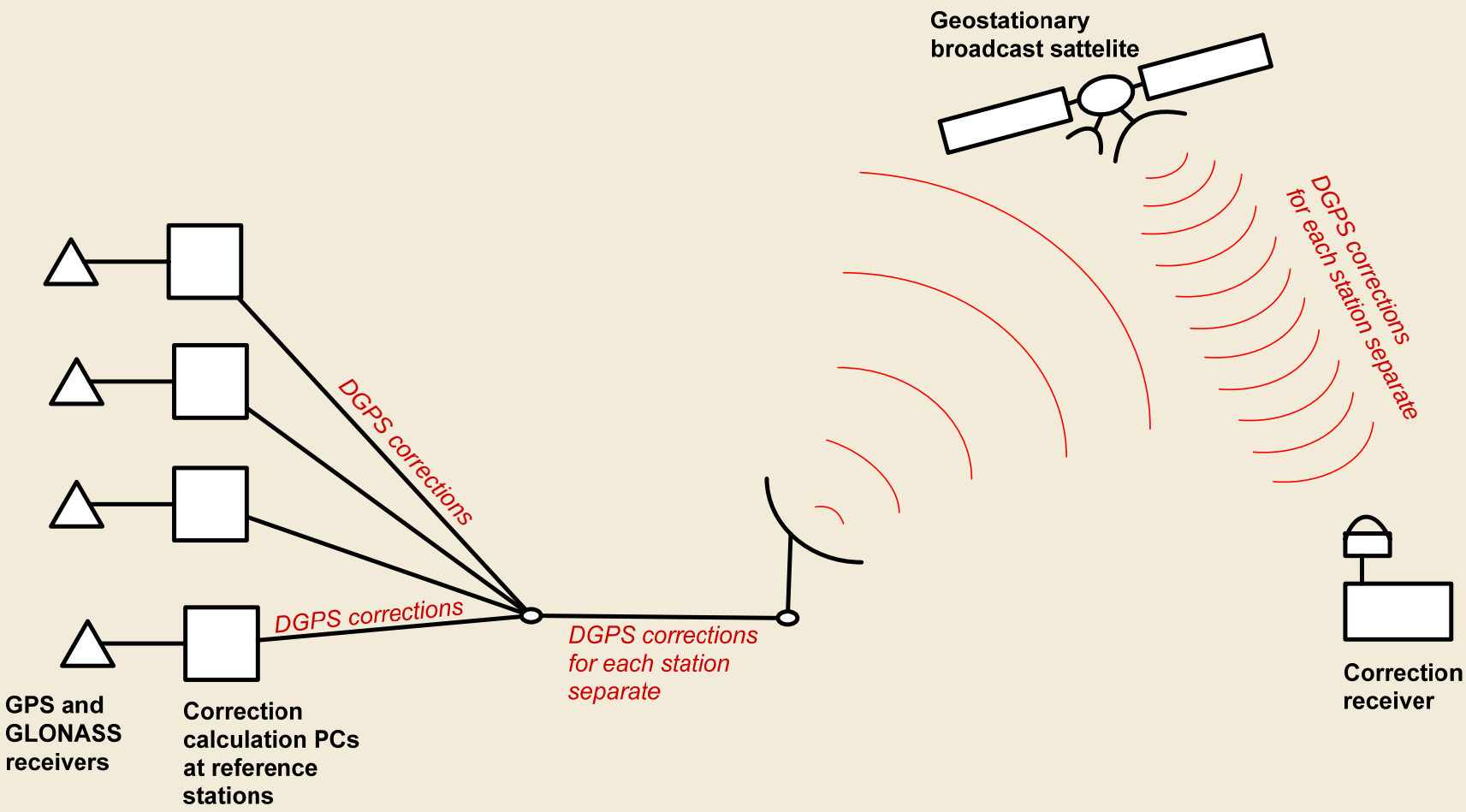
Differential (DGPS)



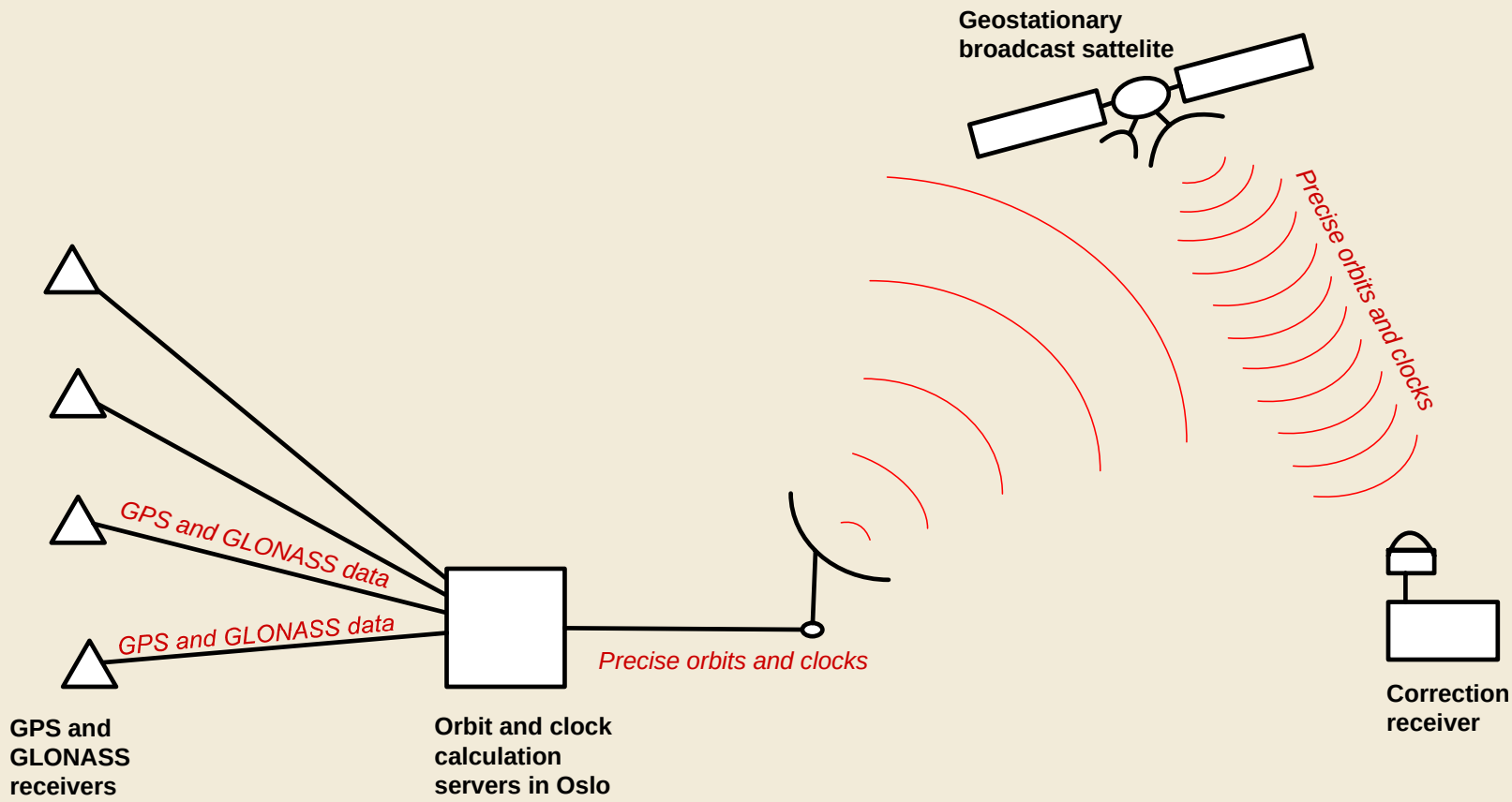
Orbit and Clock



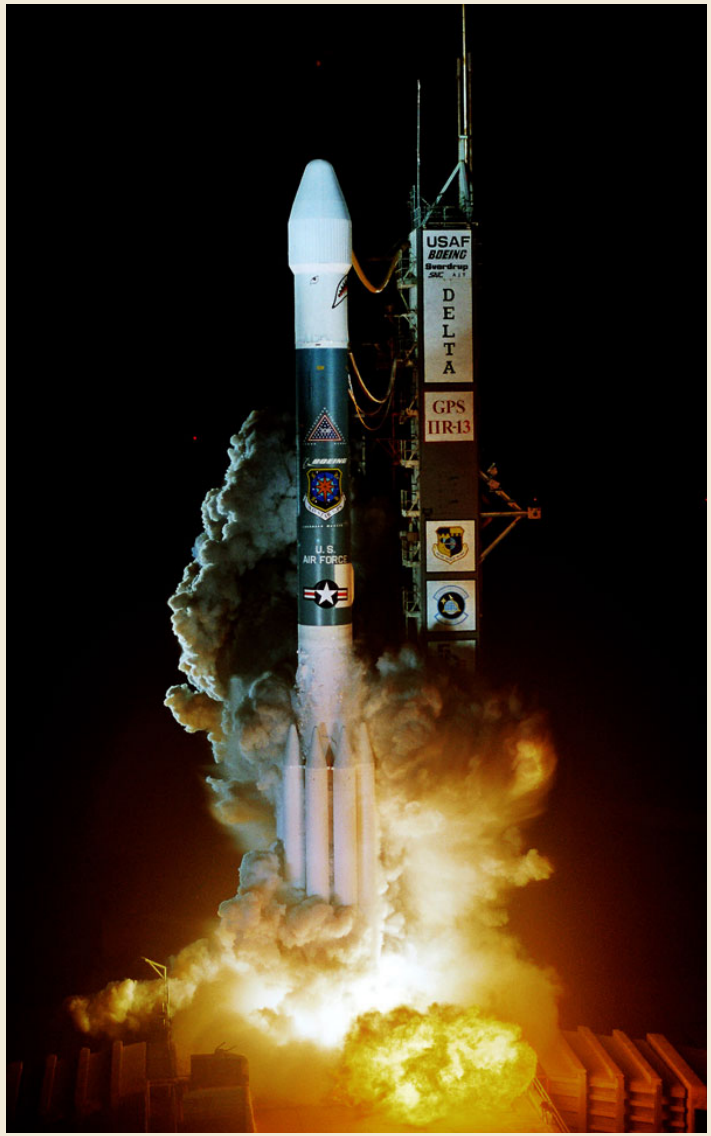
DGPS Dataflow



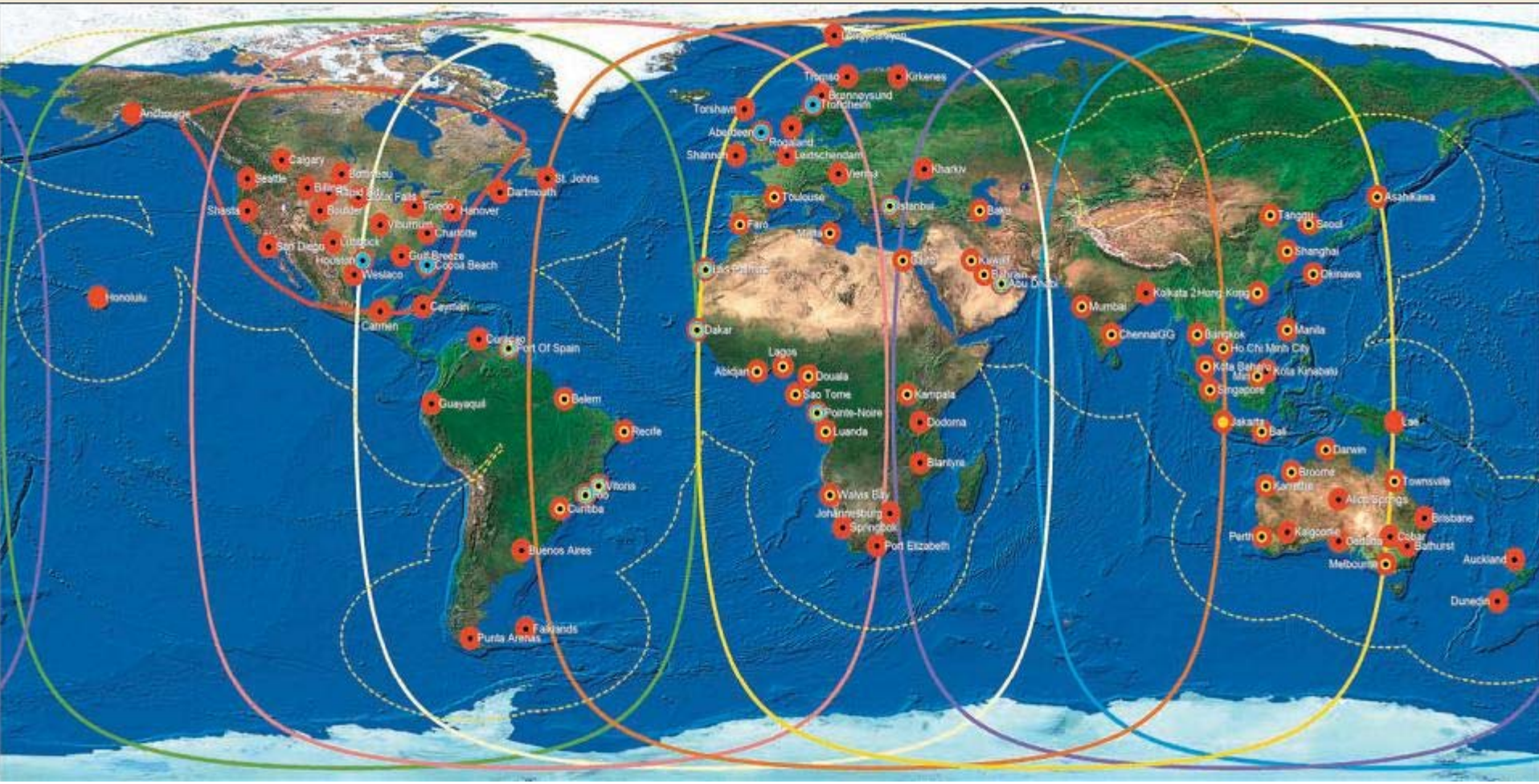
Orbit and Clock Dataflow



GPS Based High Precision Systems



Fugro Reference Station Network and Broadcasts



Index Single Freq. Dual Freq. Glonass HP

AM-SAT AMSC AORW-H AORE-H EA-SAT/AF-SAT IOR-H AP-SAT OC-SAT 2000 Km

Fugro Starfix.HP

- All elements developed and implemented by Fugro
- Uses correction data from Fugro's proprietary reference station network.
- Multi Reference Network Carrier Phase positioning computation.
- Dual Frequency
- Fugro Starfix.HP in HP Mobile and StarPack software.
- ca 30 minutes convergence time to full accuracy
- 10 cm accuracy (2 sigma) assuming a reference station within 500 km

NASA / JPL Tracking Stations

Fugro SkyFix-XP

- Hybrid system – Signals purchased from NASA / JPL, all other elements developed by Fugro
- Uses NASA / JPL managed reference stations
- Orbit and Clock “Global State Space” position computation.
- Dual Frequency system.
- MultiFix5 software.
- ca 30 minutes convergence time to full accuracy
- 10 cm accuracy (2 sigma) almost independent of location.

Return of GLONASS

GLONASS Come Back !

Russia

Putin orders completing GLONASS satellite system before 2008

14:35 | 26/12/2005

MOSCOW, December 26 (RIA Novosti) - Russian President Vladimir Putin said Monday that he wanted the GLONASS global navigation satellite system ready before 2008.

"The GLONASS system should be created before 2008, as it was originally planned," Putin told government members. "We have the possibility. Let us see what can be done in 2006-2007."

Defense Minister Sergei Ivanov said three new satellites had been successfully put into orbit Sunday to expand the navigation system.

He said 19 out of 24 GLONASS satellites were currently in orbit.

"I am convinced that by 2008, all the 24 satellites will be in orbit as part of the GLONASS federal target program," Ivanov said.

The president noted however that the satellites should be put into orbit earlier.

The first GLONASS satellite was put into orbit in 1982, but the system was officially launched in 1993.

send by e-mail >> back to main page >>

http://en.rian.ru/russia/20051226/42709745.html

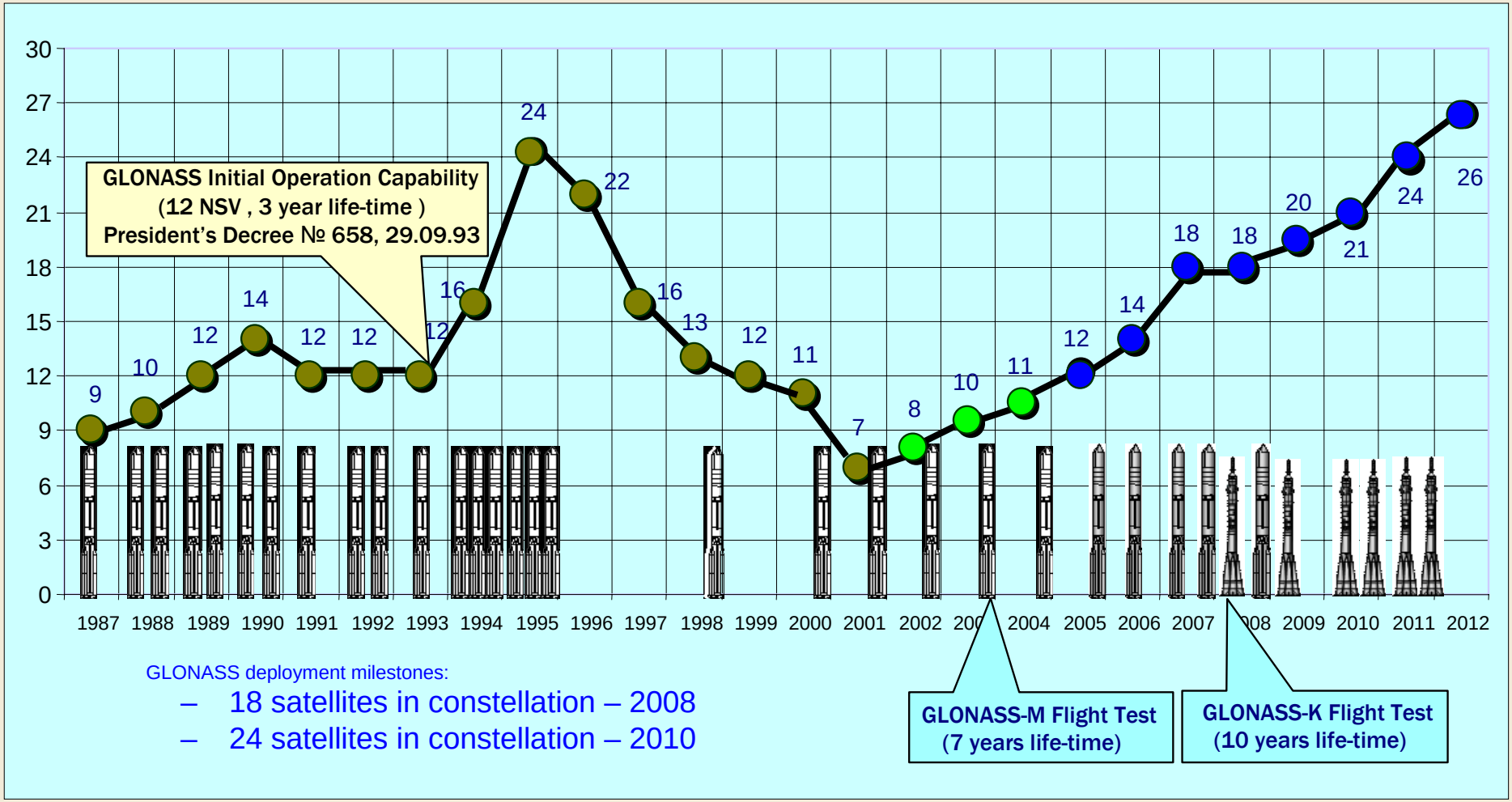
Deployment Milestones:

- 14 satellites – 2007
- 20 satellites – 2008
- 24 satellites – 2009

Performance Comparable to GPS by 2009

RUSSIAN NEWS & INFORMATION AGENCY NOVOSTI

GLONASS Constellation Deployment



16 of 17 Satellites Available

- 3 satellites launched 25 September 2008
- 3 satellites launched 26 December 2008
- 6 satellites to be launched 2009 and in 2010
- USD 2.6 Billion allocated for operations 2012-2020

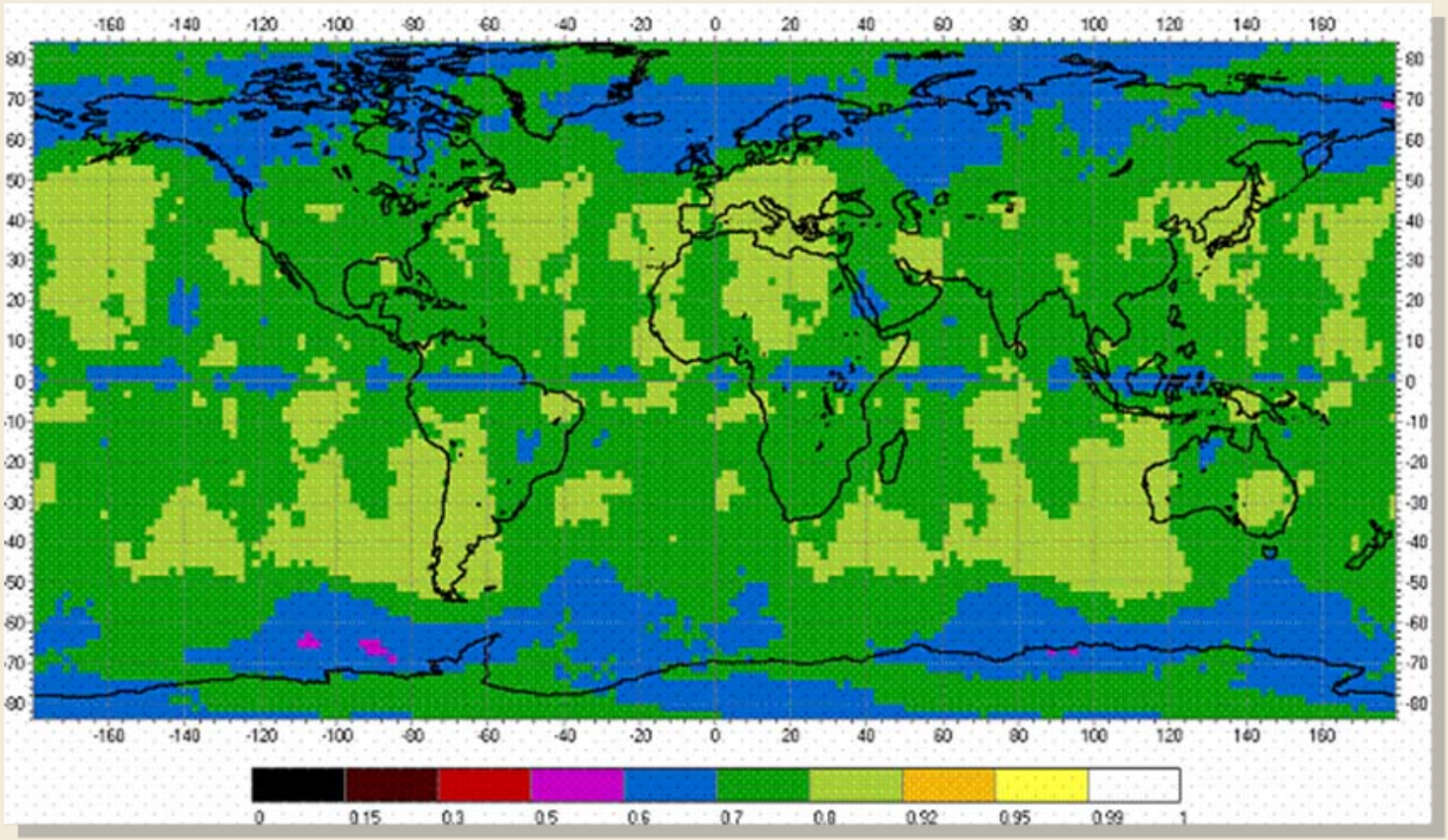
GLONASS Constellation Status at 01.12.2008 based on both the almanac analysis and navigation messages received at 10:00 01.12.08 (UTC) in IAC PNT TsNIImash

Orb. pl.	Orb. slot	RF chnl	# GC	Launched	Operation begins	Operation ends	Life-time (months)	Satellite health status		Comments
								In almanac	In ephemeris (UTC)	
I	4	06	795	10.12.03	29.01.04		59.8	+	+ 08:45 01.12.08	In operation
	6	01	701	10.12.03	08.12.04		59.8	+	+ 10:15 01.12.08	In operation
	7	05	712	26.12.04	07.10.05		47.2	+	+ 10:15 01.12.08	In operation
II	9	-2	722	25.12.07	25.01.08		11.2	+	+ 06:44 01.12.08	In operation (L1 only)
	10	04	717	25.12.06	03.04.07		23.2	+	+ 08:15 01.12.08	In operation
	11	00	723	25.12.07	22.01.08		11.2	+	+ 09:47 01.12.08	In operation
	13	-2	721	25.12.07	08.02.08		11.2	+	+ 10:15 01.12.08	In operation
	14	04	715	25.12.06	03.04.07		23.2	+	+ 10:15 01.12.08	In operation
	15	00	716	25.12.06	12.10.07		23.2	+	+ 03:15 01.12.08	In operation
III	17	-1	718	26.10.07	04.12.07		13.2	+	+ 04:00 01.12.08	In operation
	18	-3	724	25.09.08	26.10.08		2.2	+	+ 06:00 01.12.08	In operation
	19	03	720	26.10.07	25.11.07		13.2	+	+ 07:45 01.12.08	In operation
	20	02	719	26.10.07	27.11.07		13.2	+	+ 09:15 01.12.08	In operation
	21	-1	725	25.09.08	05.11.08		2.2	+	+ 10:15 01.12.08	In operation
	22	-3	726	25.09.08	13.11.08		2.2	+	+ 10:14 01.12.08	In operation
	23	03	714	25.12.05	31.08.06		35.2	+	+ 10:15 01.12.08	In operation
	24	02	713	25.12.05	31.08.06		35.2	+	+ 02:28 01.12.08	In operation

Total satellites in constellation	19 SC
Operational	14 SC
In commissioning phase	3 SC
In maintenance	1 SC
In decommissioning phase	1 SC

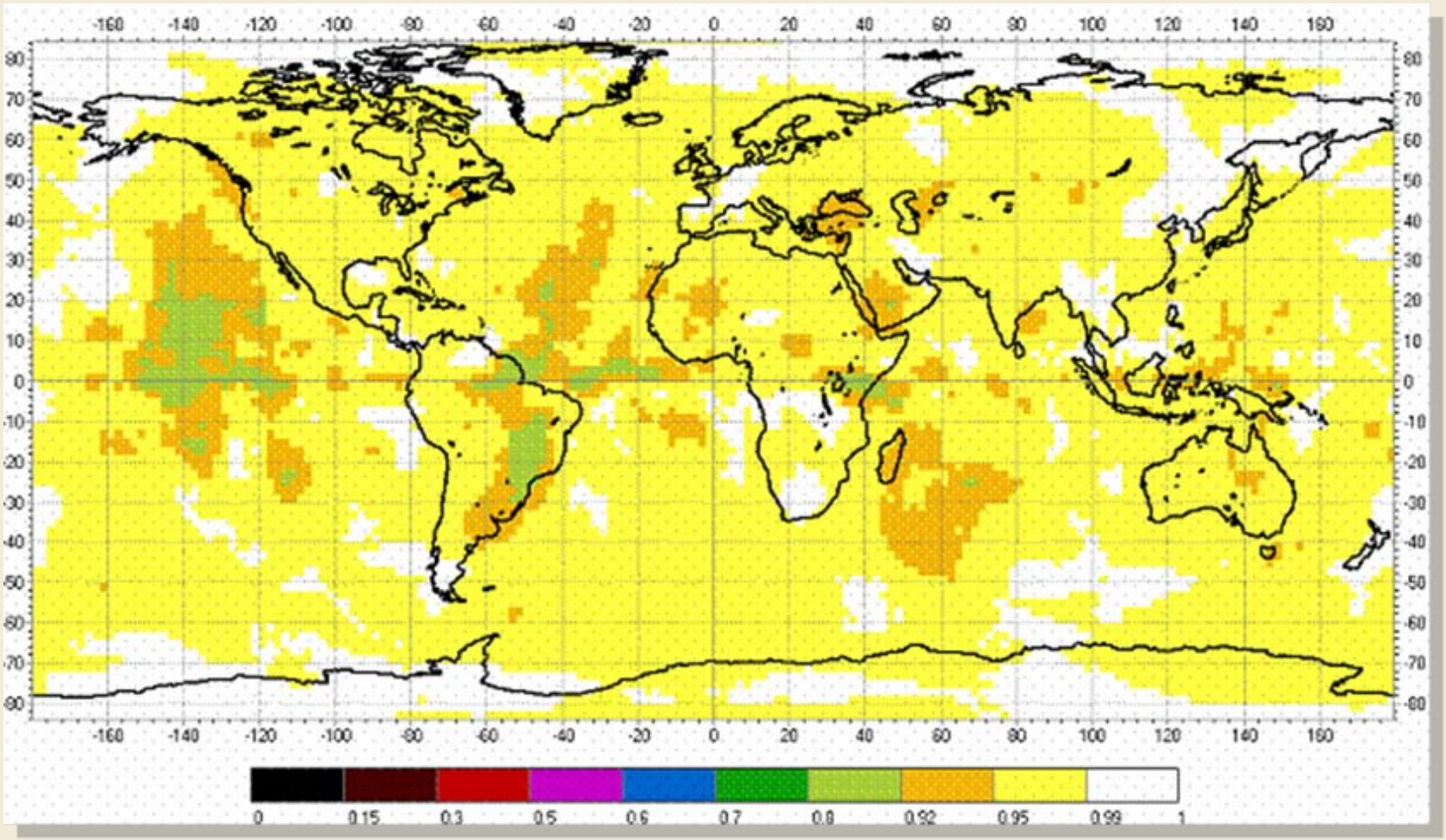
GPS Coverage

Probability that GDOP<5 for mask angle of 25° (a case for urban canyon)

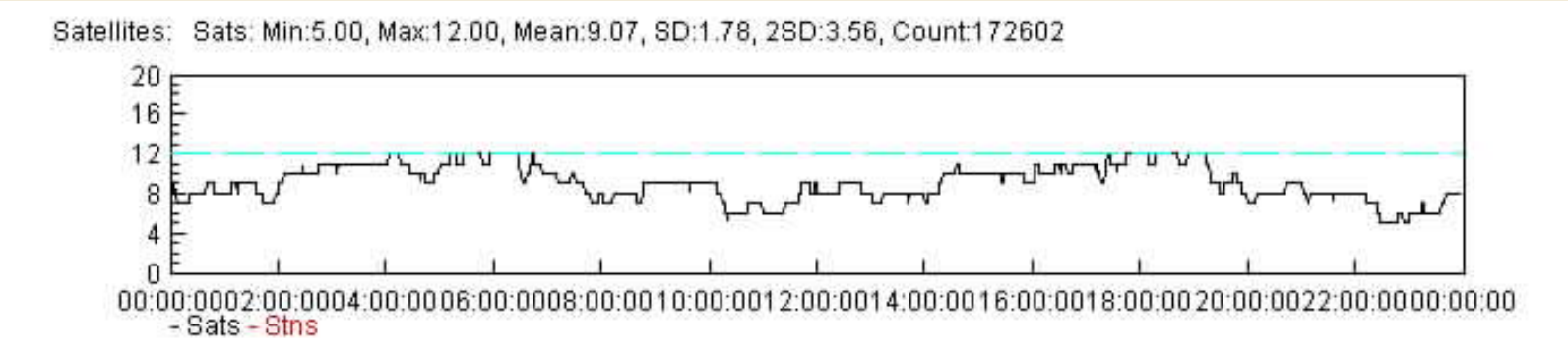


GPS and GLONASS Coverage

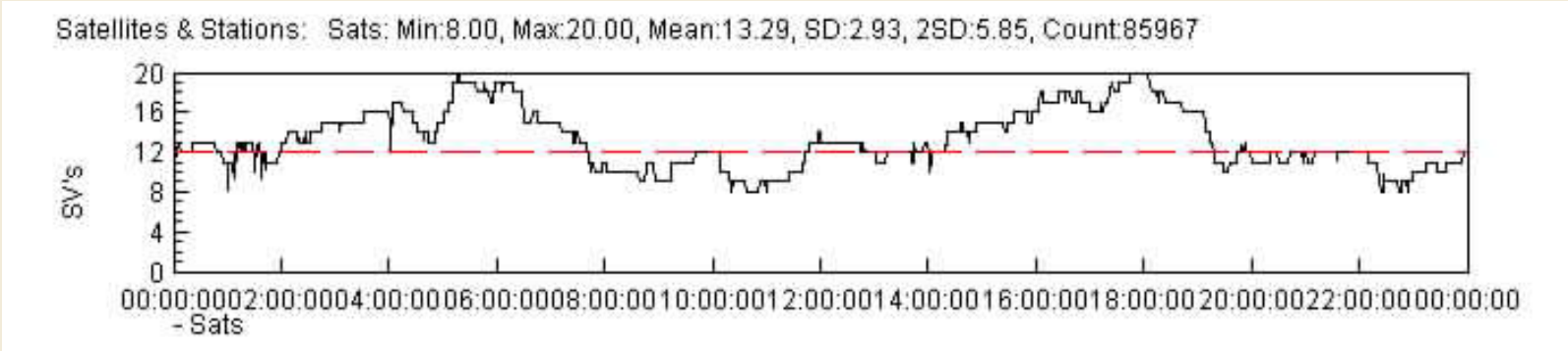
Probability that GDOP<5 for mask angle of 25° (a case for urban canyon)



Number of Satellites Available, Elevation Mask 8°



GPS: Mean: 9 satellites



GPS+GLONASS: Mean: 13 satellites


USAF
BOEING
DELTA
GPS
IIR-15

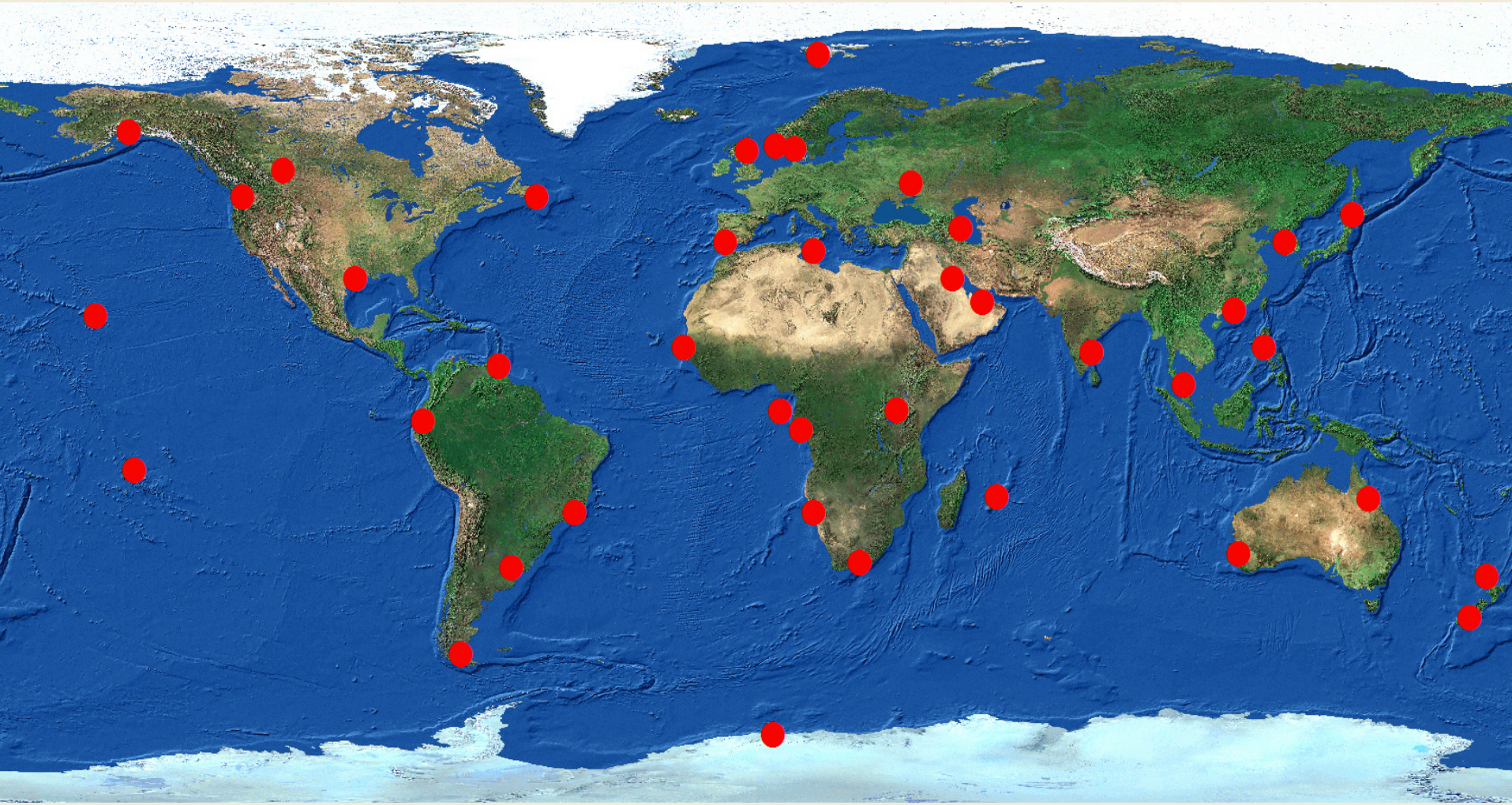
GPS & GLONASS PPP
Utilising Fugro Derived Corrections

Development History

- Key Milestones:
  - The G2 concept was conceived around year 2000
  - A development contract was signed February 2003 with ESA and the development started
  - The decision to include GLONASS was made in October 2004
  - G2 test signal on the air from February 2008

- Fugro's Motivation
  - Precise orbit and clock is the future
  - Fugro develops this technology further
    - Solution Independent of JPL
    - Addition of GLONASS

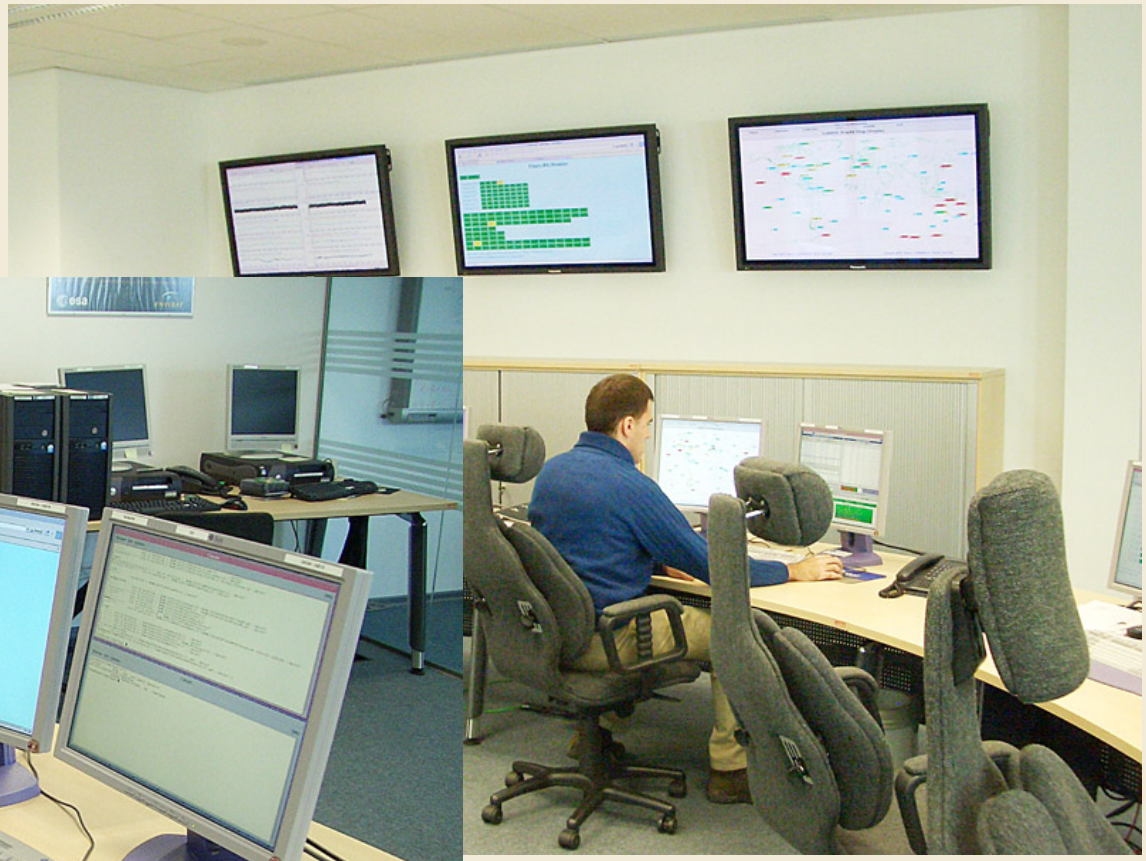
G2 Infrastructure



Currently about 35 stations

Operations and Monitoring Centre, Oslo

Support Team at ESA

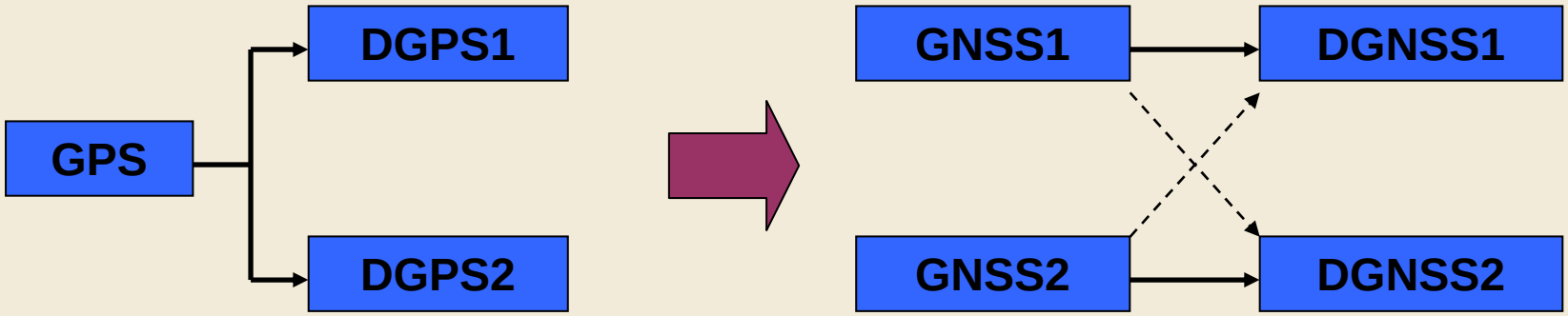


Advantages of Combined GNSS Systems

Improved Performance with Several GNSS

- Independence
  - When more systems become fully operational, they can be used as independent systems in safety critical applications
- Availability
  - Combined systems will improve availability of satellite navigation in situations where parts of the sky are obscured. This will be the case close to oil rigs, during ionosperic scintillations etc.
- Reliability
  - Increased redundancy of data (additional lines of position) will help to identify bad measurements
- Accuracy
  - Improved accuracy with more satellites (improved geometry)
  - Improved convergence time in phase based decimeter level systems

- Independence
  - Today GPS is used in all satellite navigation reference systems
  - When more systems become fully operational, they can be used as independent systems in safety critical applications



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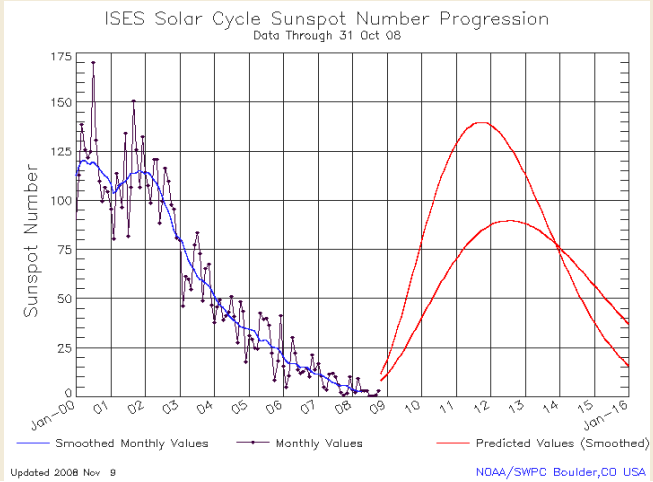
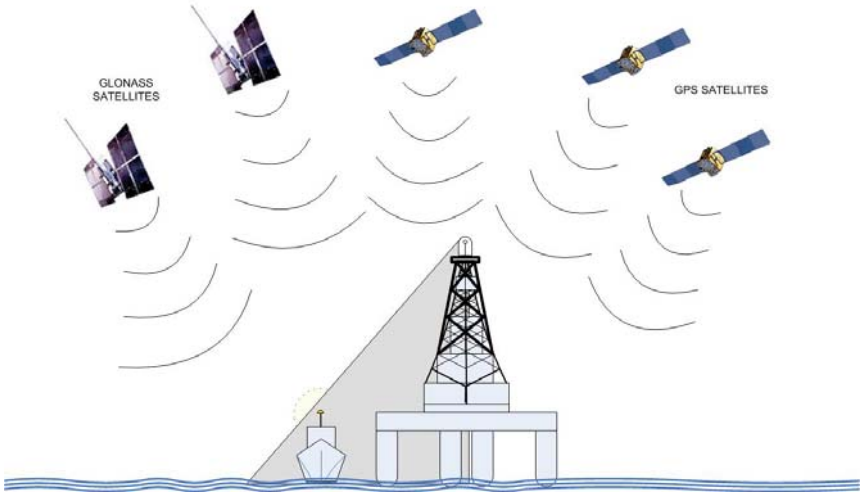
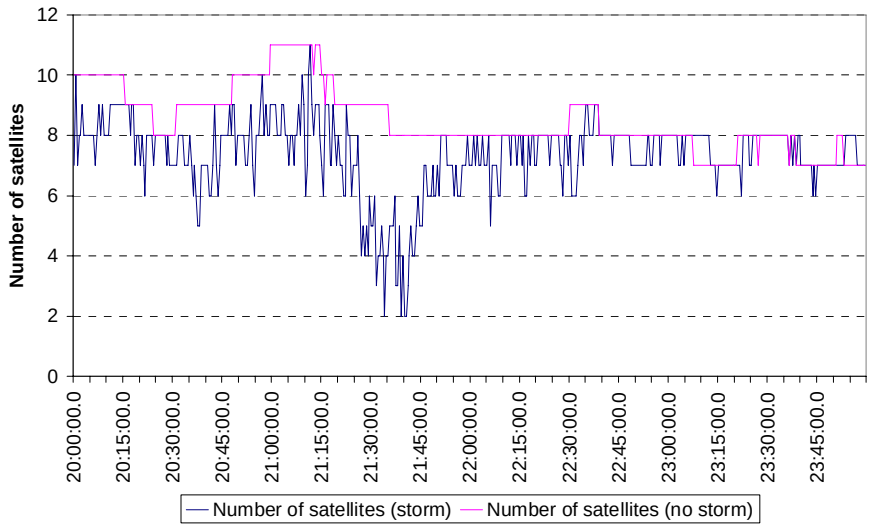
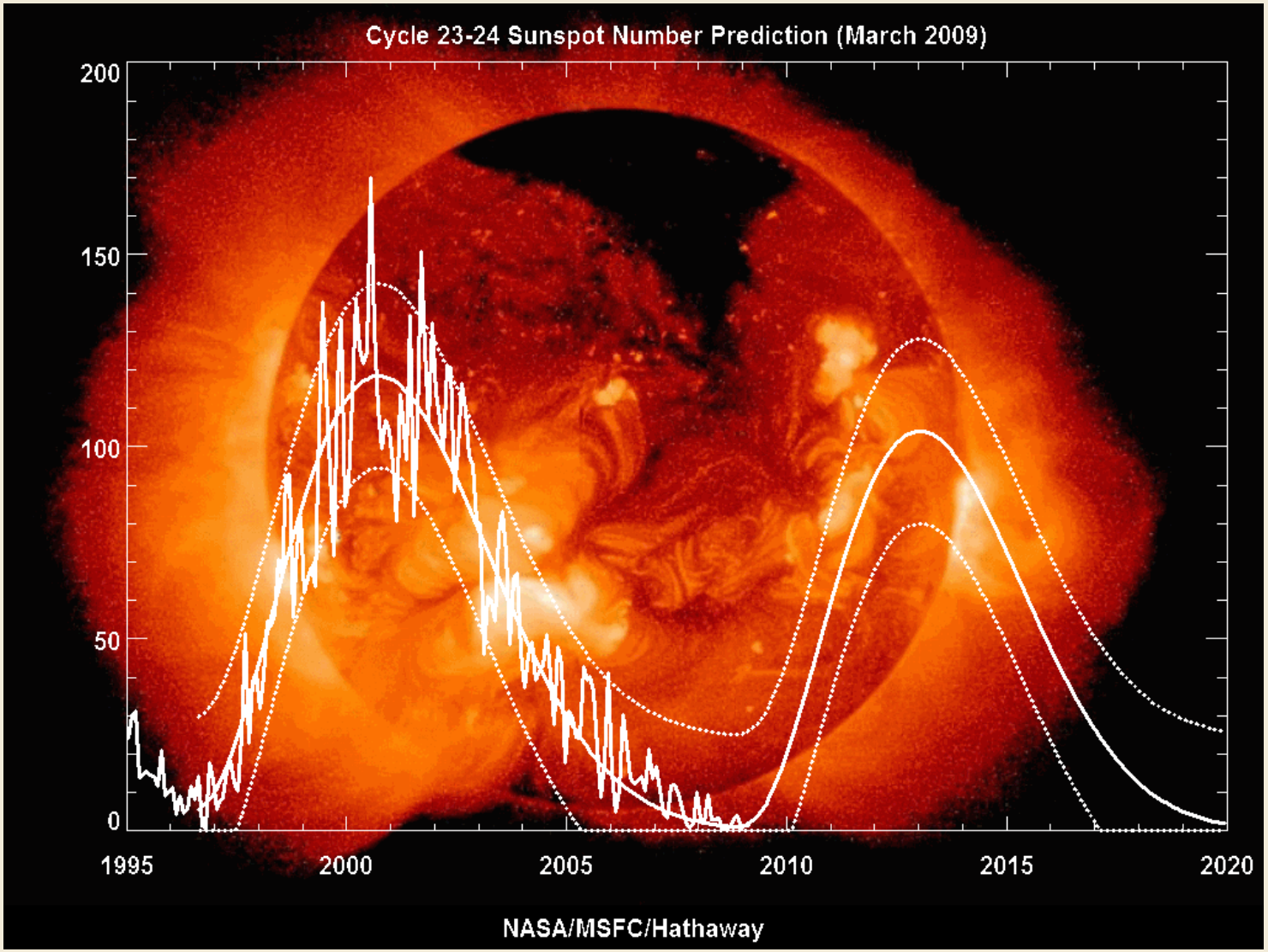


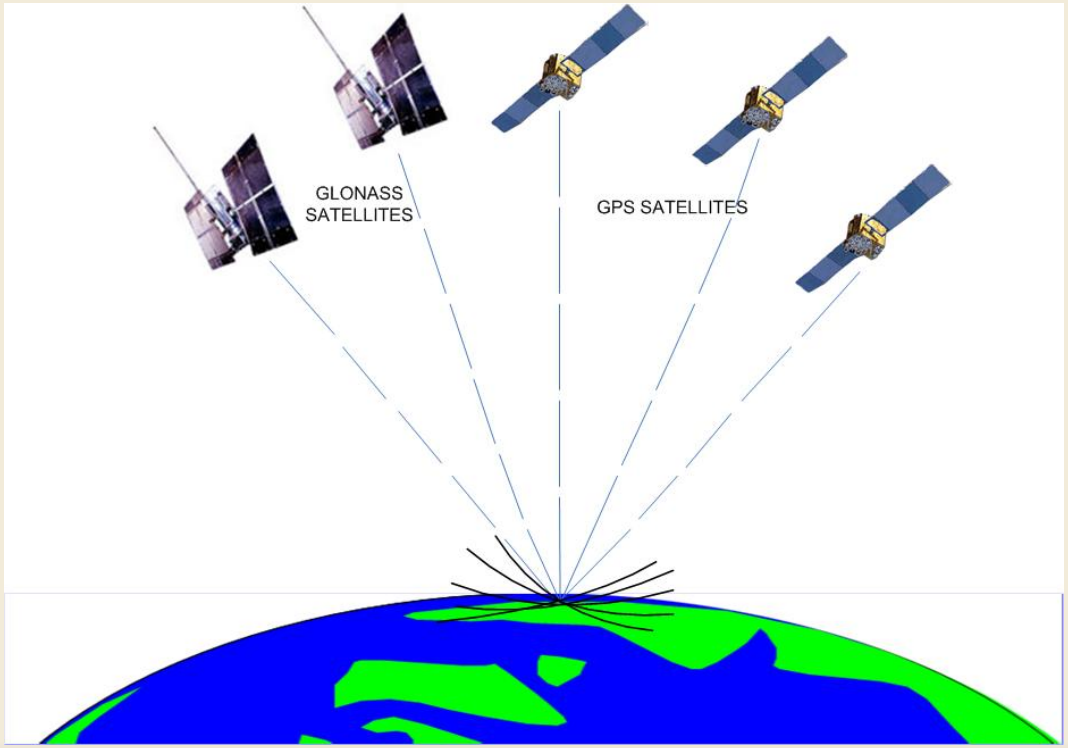




Solar Cycle 23 - 24



- Reliability
  - Increased redundancy of data (additional lines of position) will help to identify bad measurements
    - RAIM = Receiver Autonomous Integrity Monitoring
    - Also a part of UKOOA Guidelines

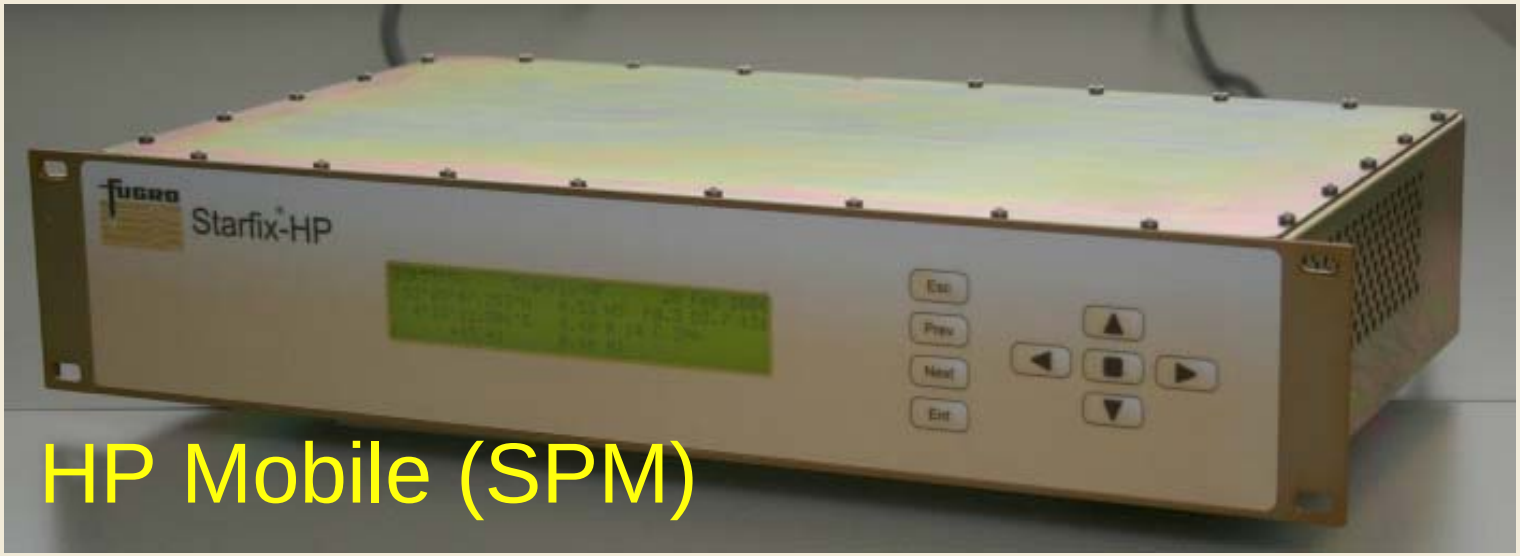


Orbit and Clock versus DGPS:

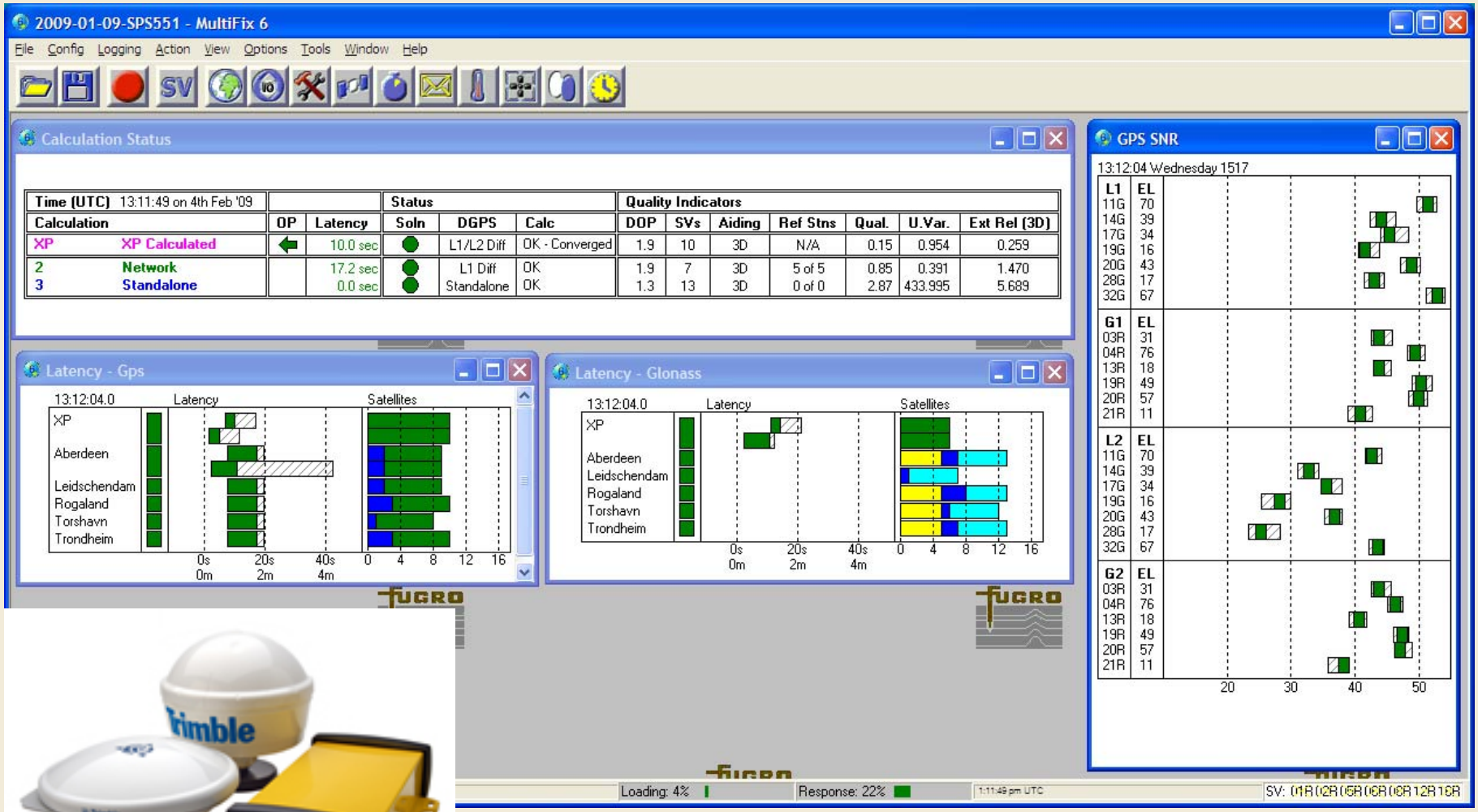
1. Requires fewer reference stations than differential (global coverage)
2. One set of correction data valid everywhere
3. No baseline (“distance to ref. station”) dependent errors
4. Independence from local reference station performance
5. Better correction data during ionospheric storms
6. High redundancy and robustness


LMWI
H-87-AV BIRKELAND

Survey / Positioning Hardware Implementation

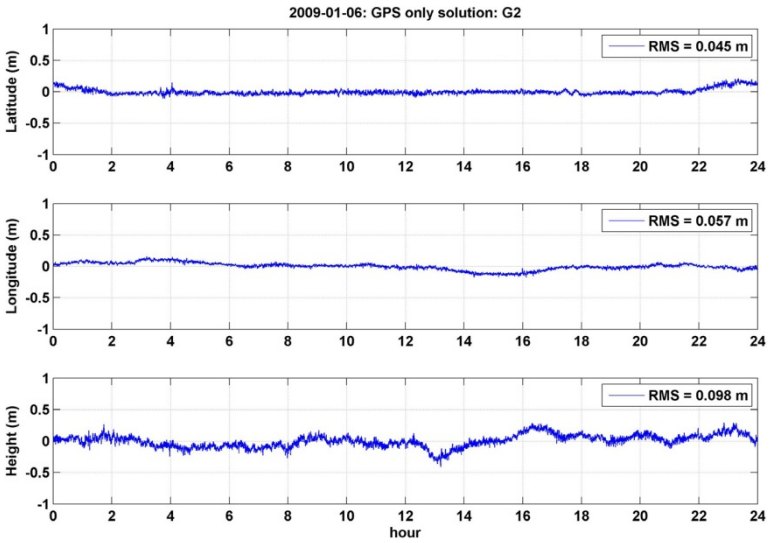


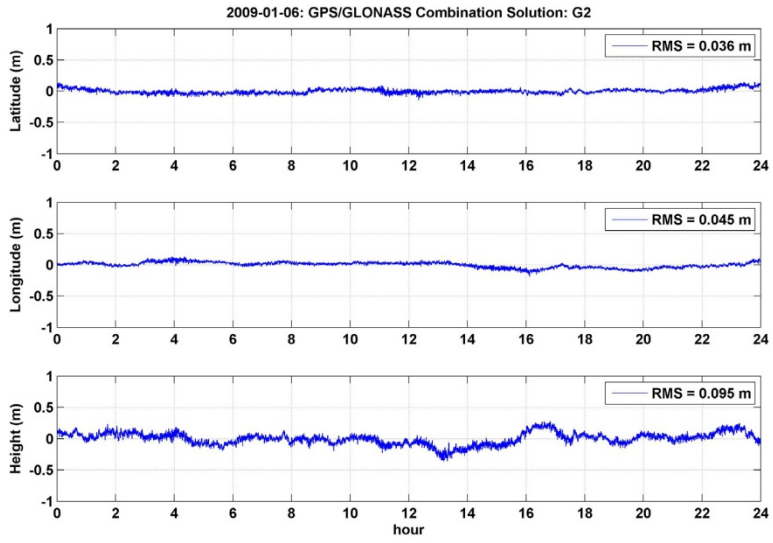
Survey / Positioning Software Implementation

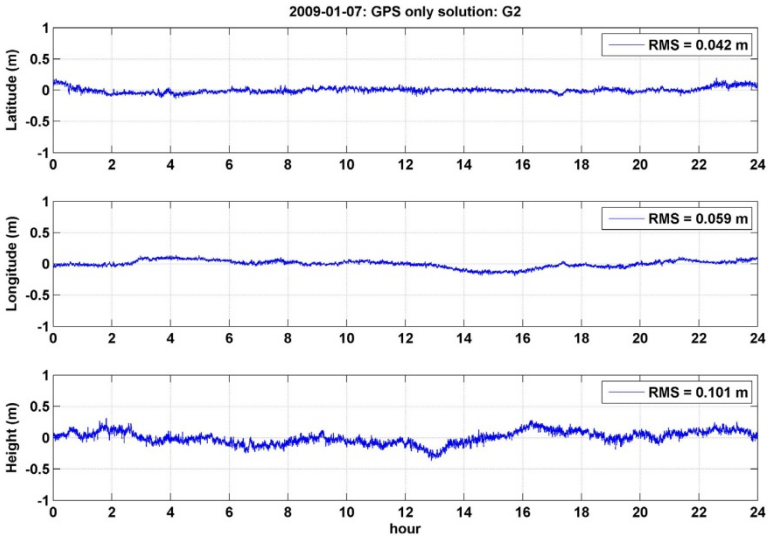


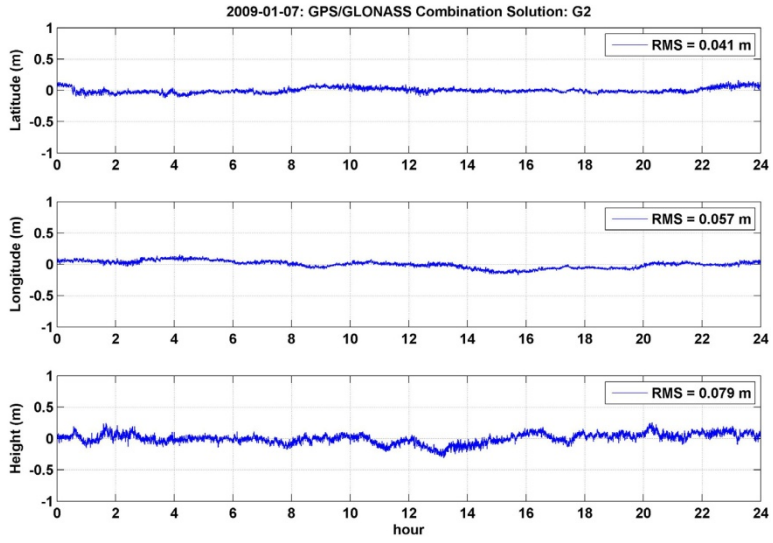
MultiFix6 Software

January 2009 – GPS Versus GPS & GLONASS

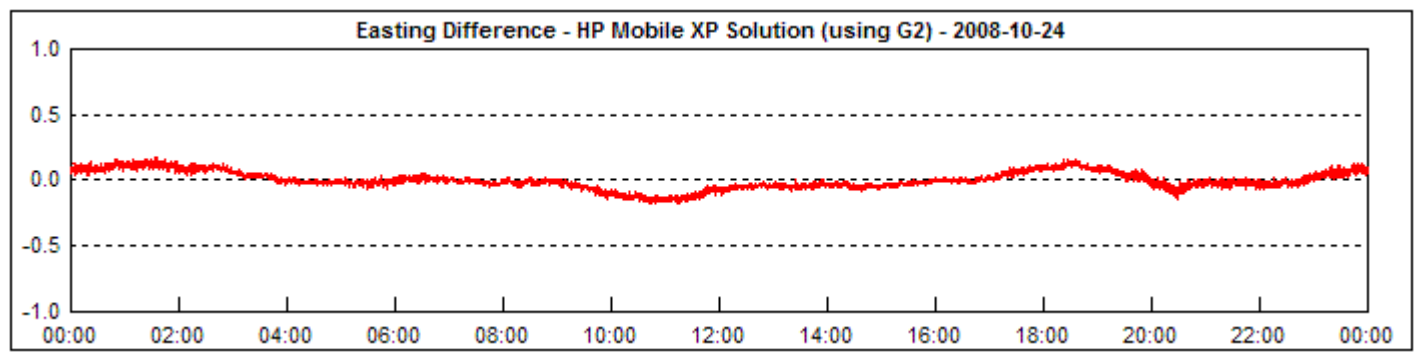


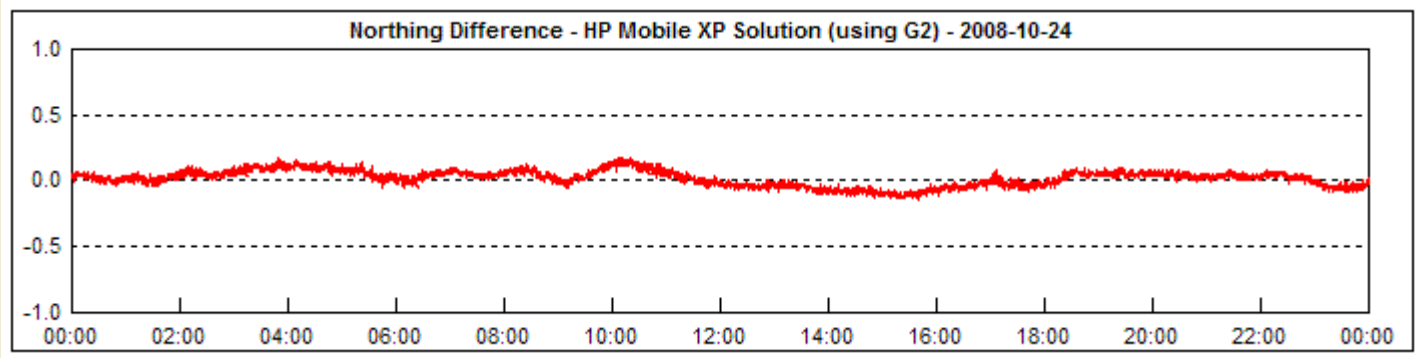


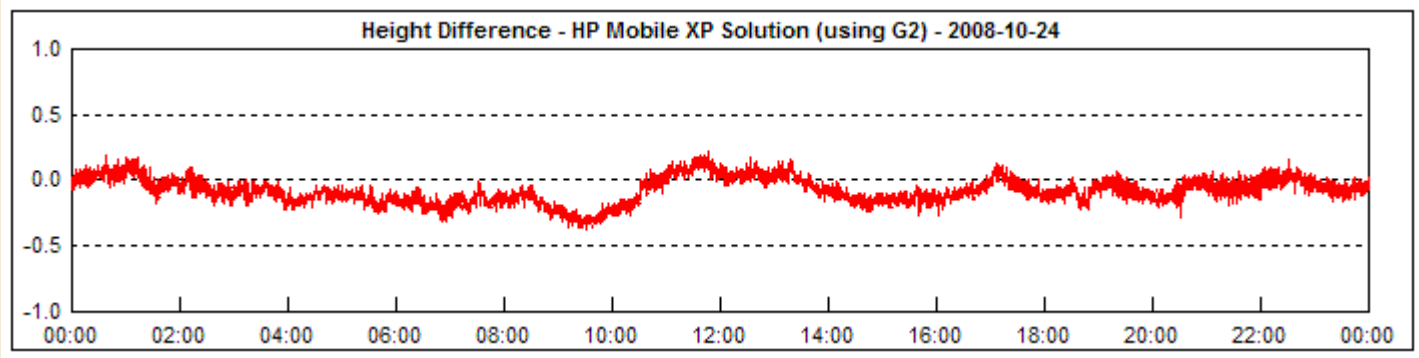




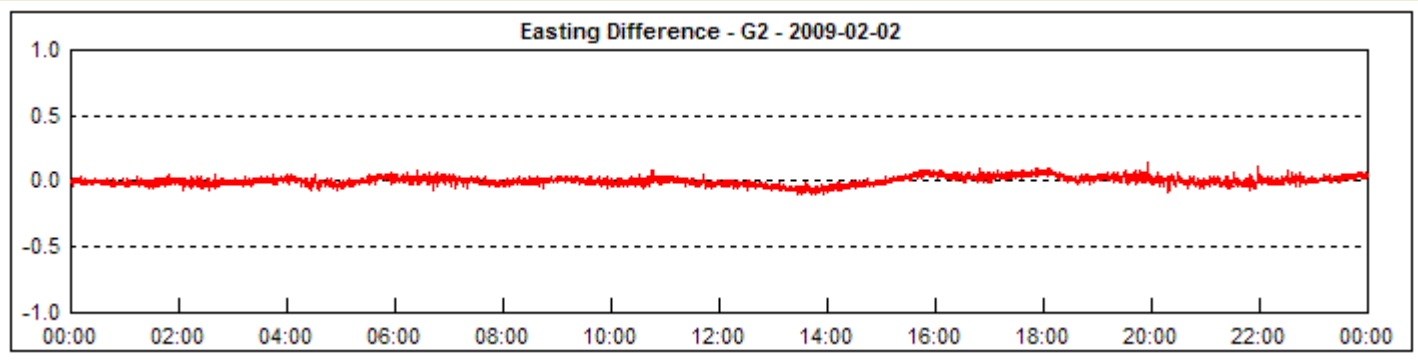
Early System Performance – October 2008

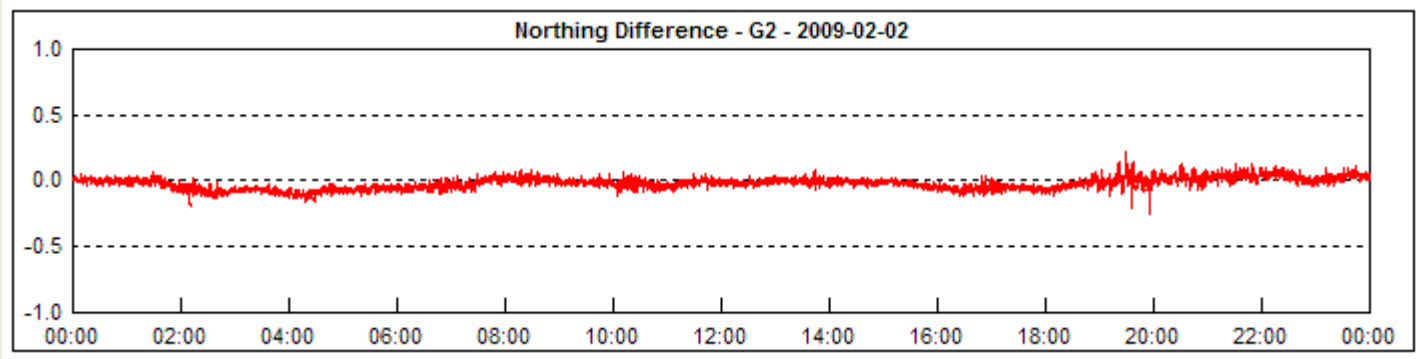


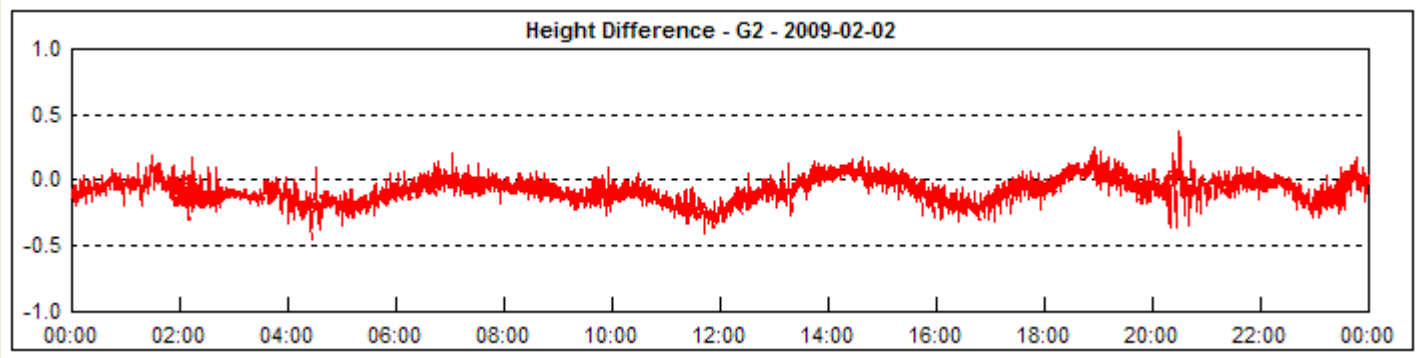




System Performance – February 2009







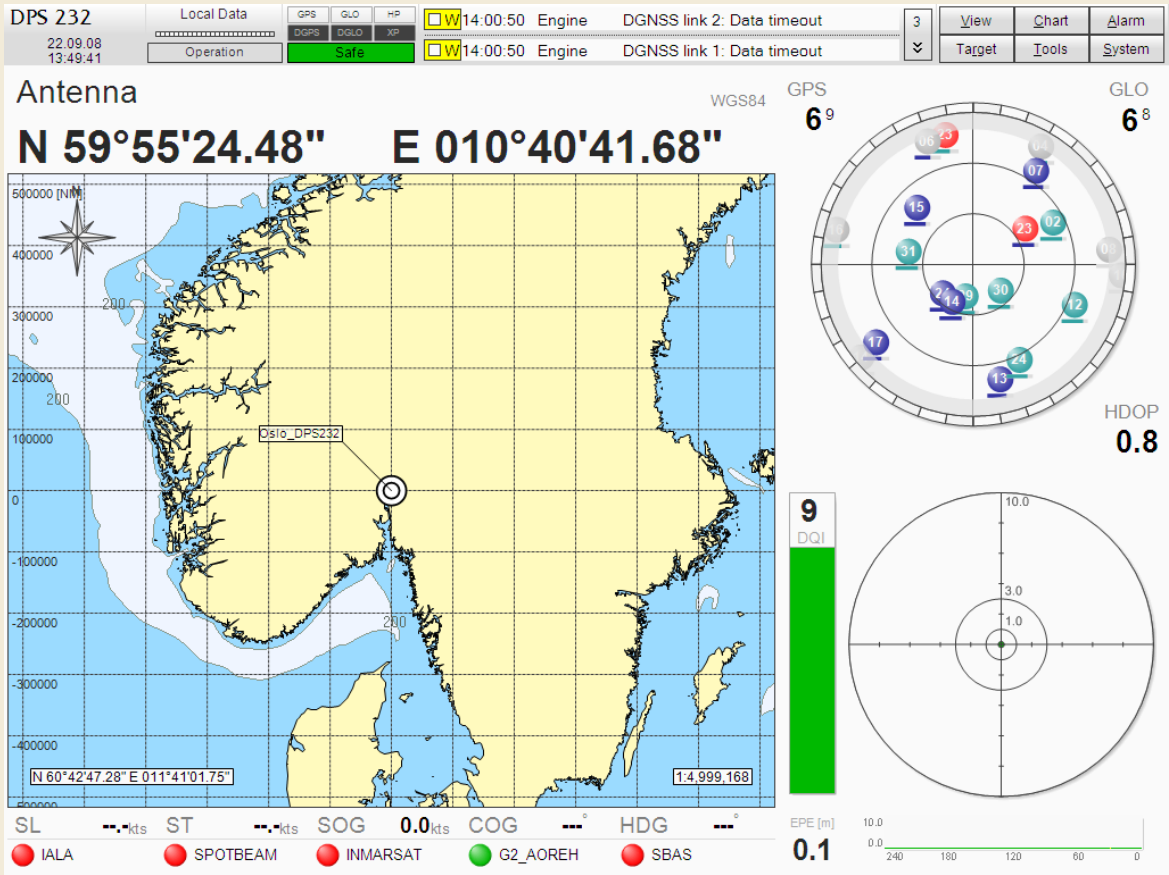
G2 Performance Summary

	Accuracy (95%)			Precision (95%)		
Date	**Easting**	**Northing**	**Height**	**Easting**	**Northing**	**Height**
24 Oct 2008	-0.001 m	0.017 m	0.088 m	0.126 m	0.110 m	0.233 m
2 Feb 2009	0.003 m	-0.023 m	-0.075 m	0.055 m	0.088 m	0.221 m

Accuracy (Reliability): Offset from a “known” geodetic point.

Precision: Spread of data.

Kongsberg Seatex DPS 232
Dual Frequency GPS / GLONASS
Uses new Fugro correction service.



Fugro Branded
Trimble 9200-G2

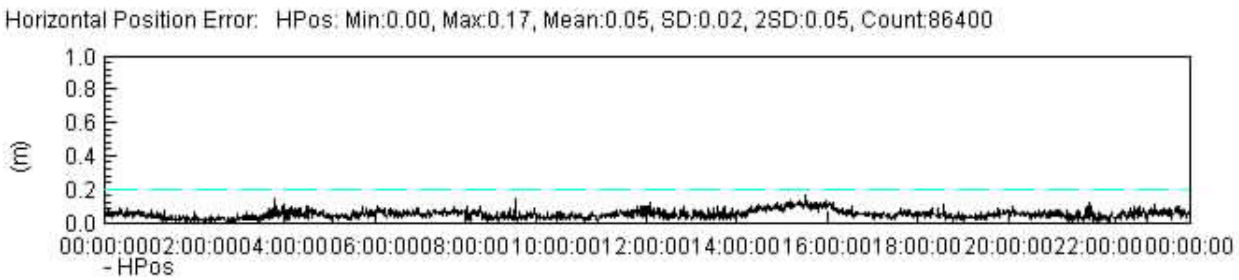
Kongsberg Seatex DPS232 Tests, 6 January 2009

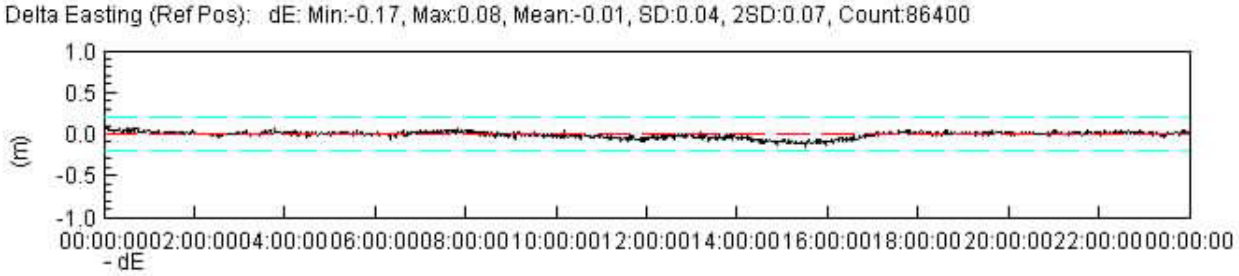
Horizontal Error

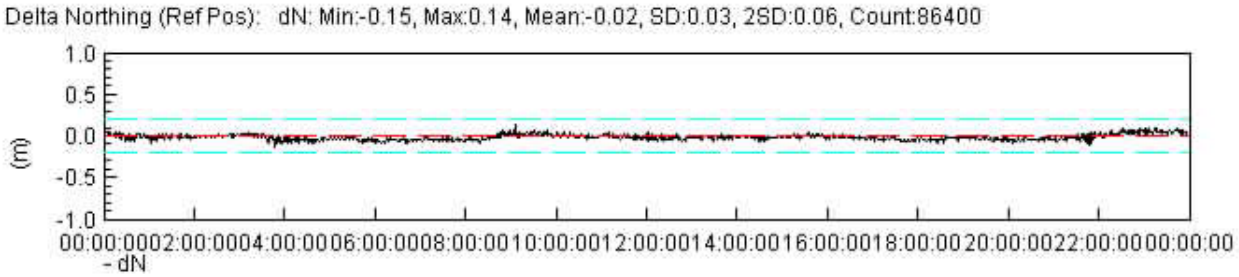
East Error

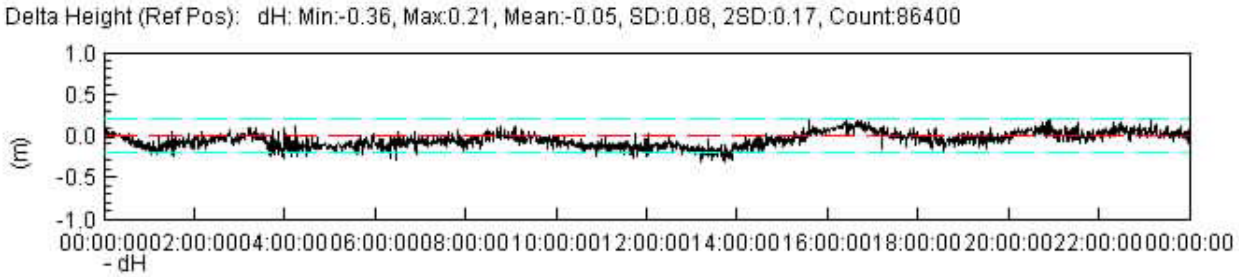
North Error

Height Error









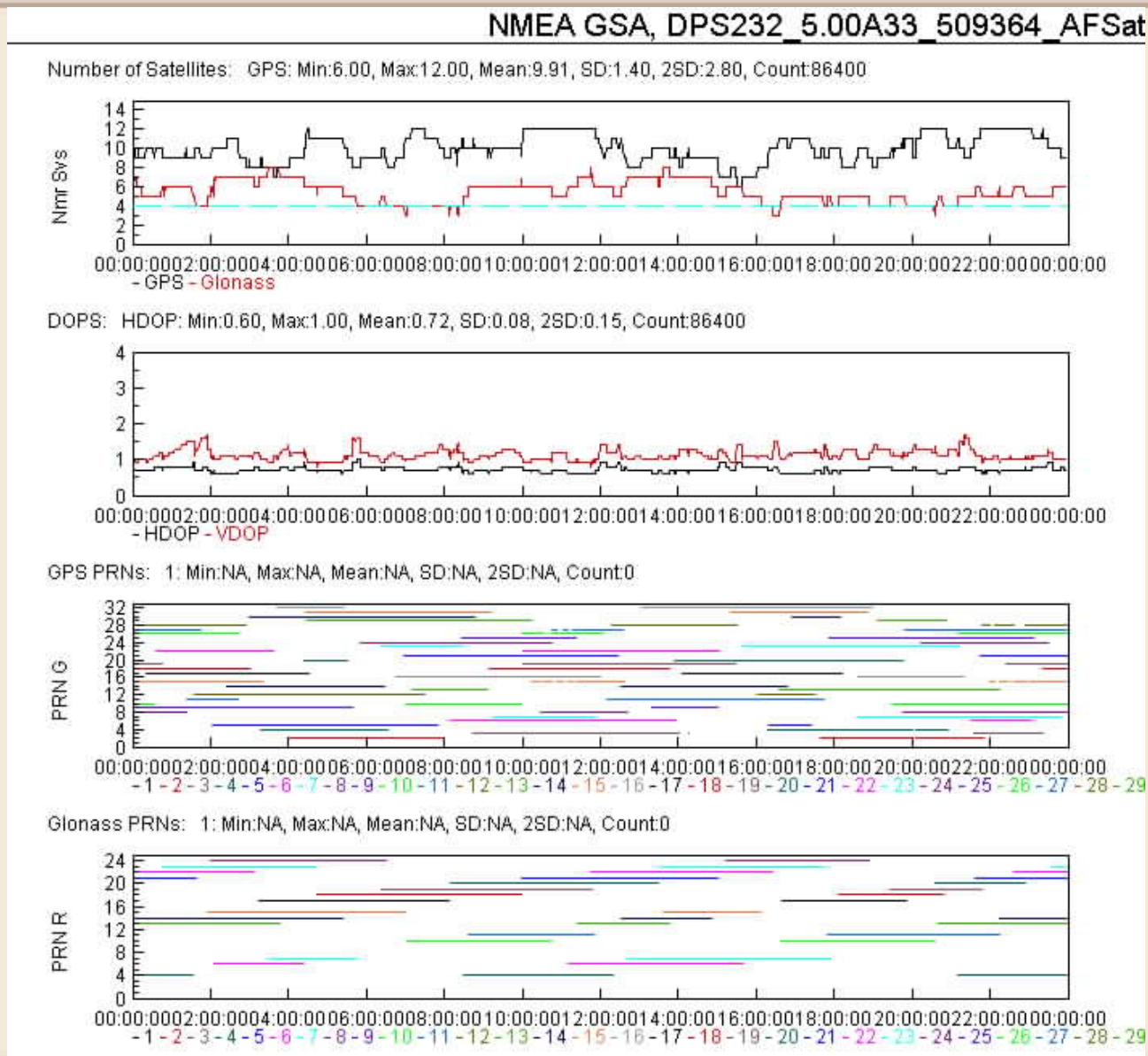
Kongsberg Seatex DPS232 Tests, 6 January 2009

No of Satellites

HDOP,VDOP

GPS PRNs

GLONASS PRNs



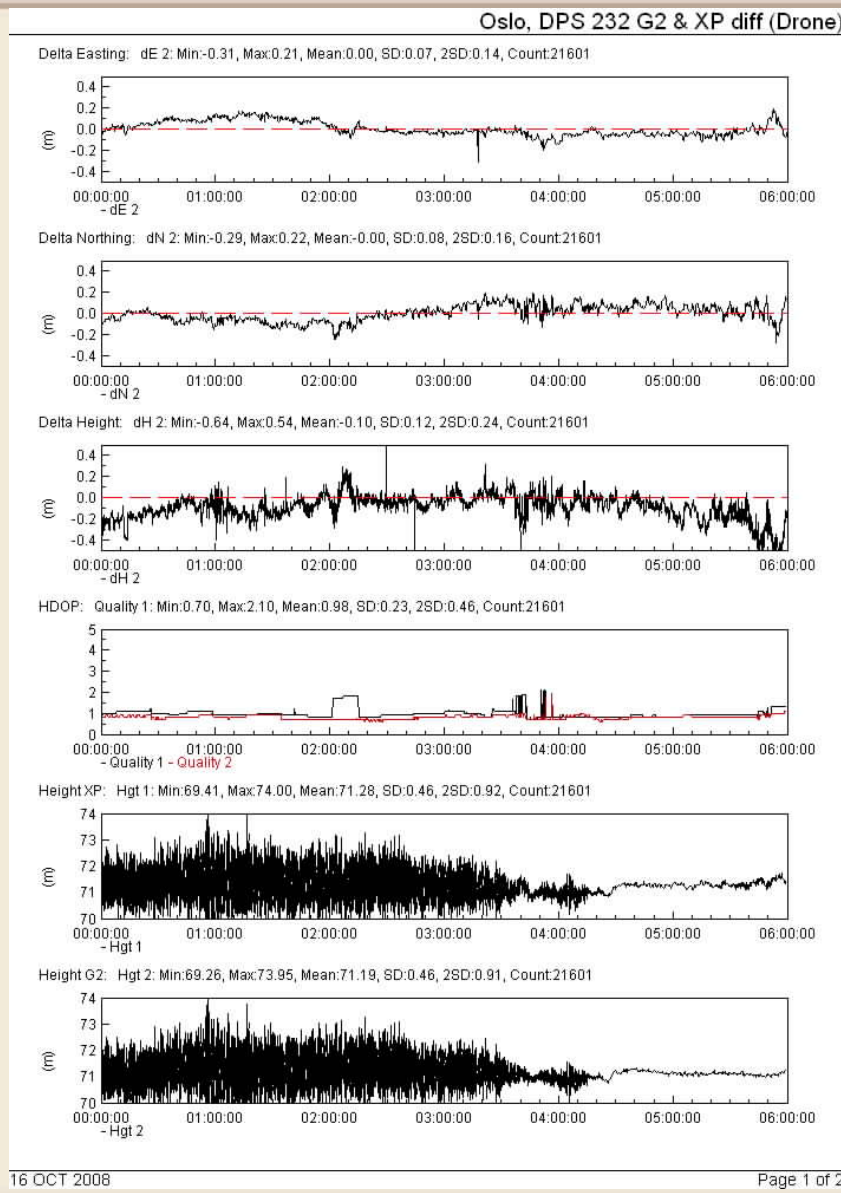
Dynamic Trials onboard Bourbon Topaz

- Seatex DPS 232 in G2 mode
- Seatex DPS 232 in XP mode

- Both connected to the same antenna

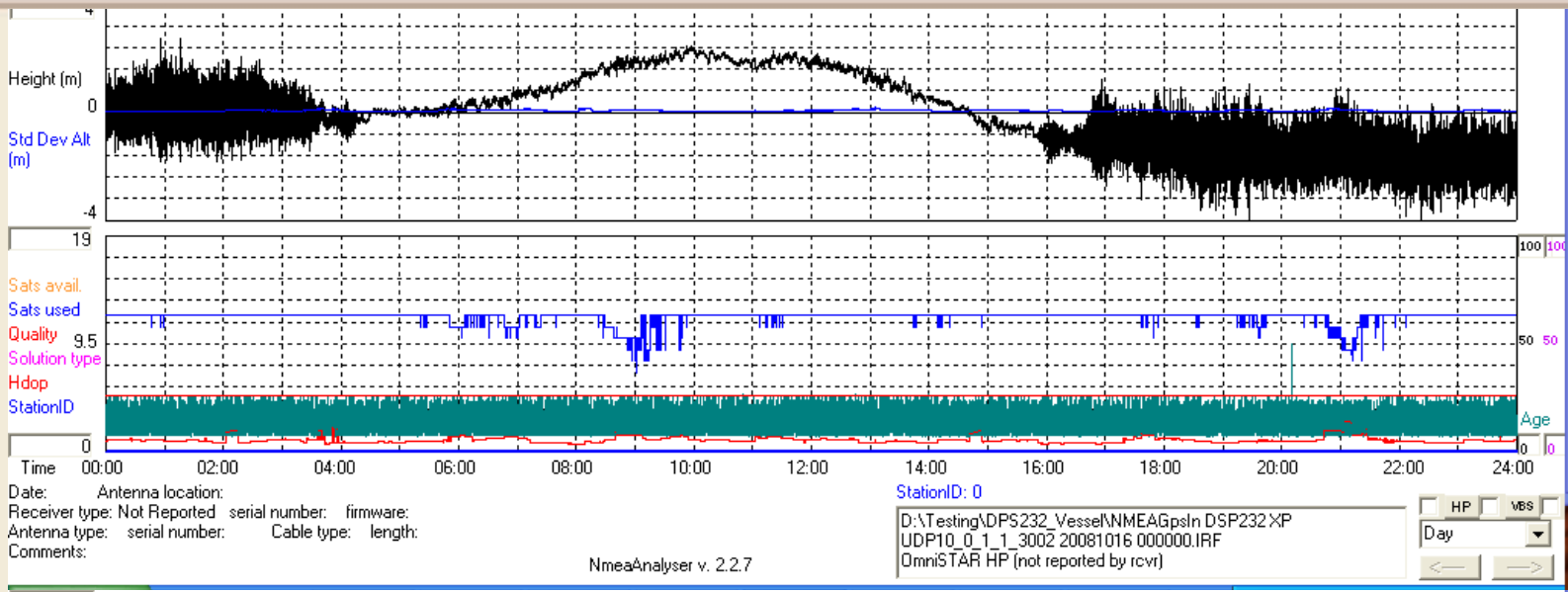
Bourbon Topaz – 16 October 2008

- Difference between G2 and XP in Easting, northing and height, 6 hours
- HDOP in G2 (2) and XP (1)
- Height in XP and HP
  (2-3 m heave at sea, at harbour 04:30)

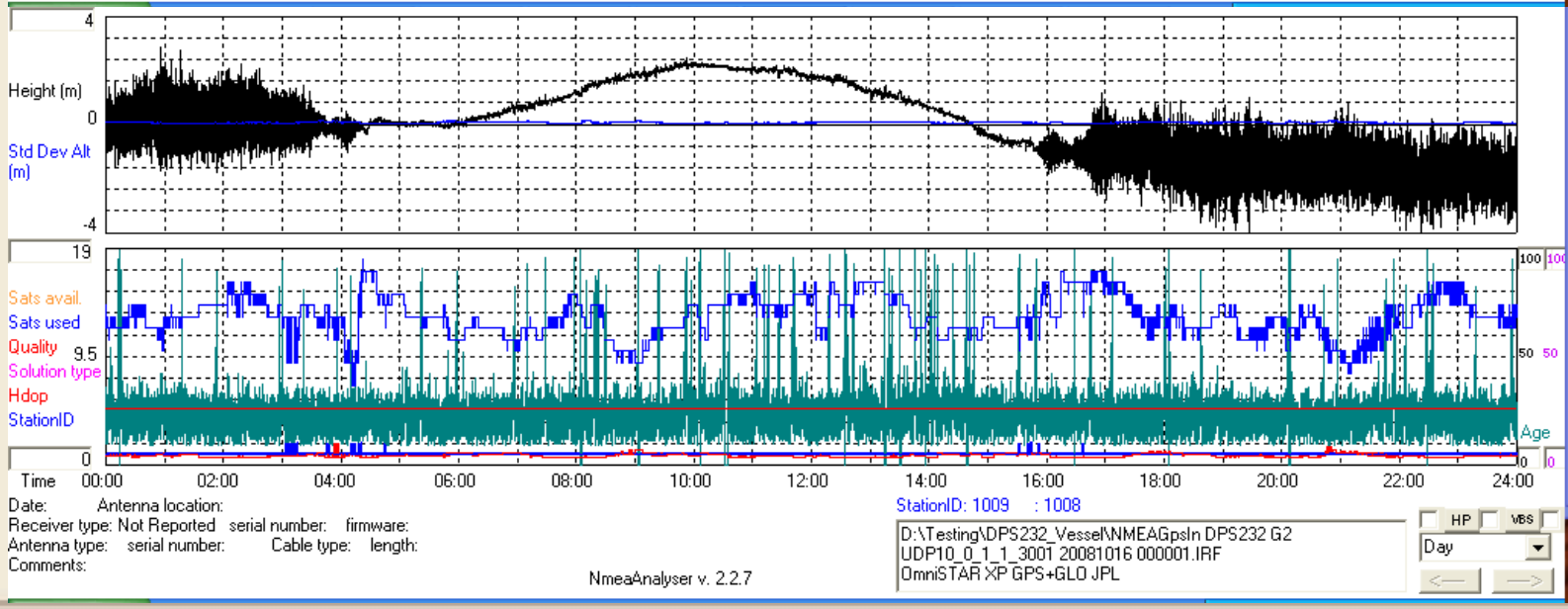


Bourbon Topaz – 16 October 2008

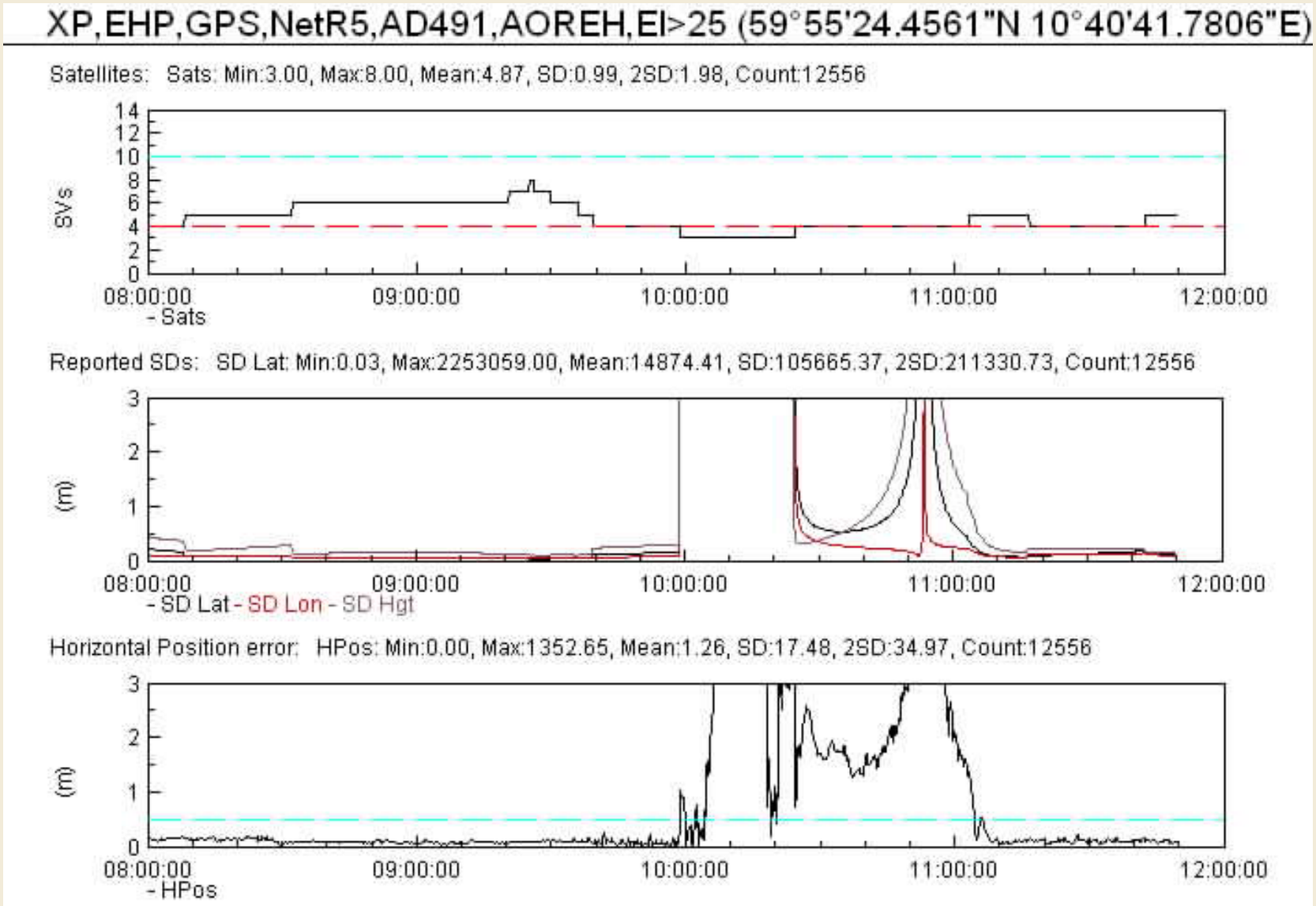
XP, 24hours



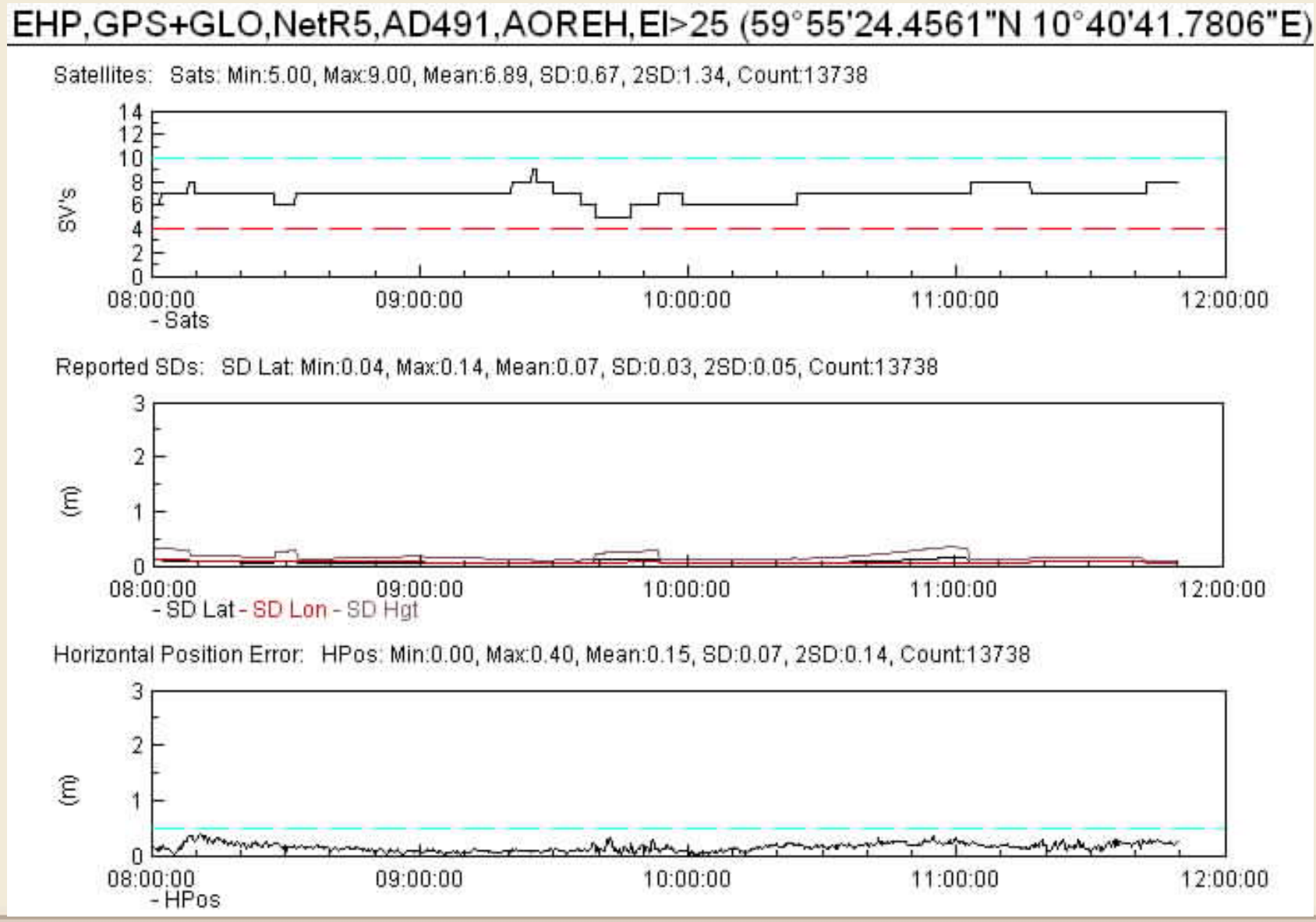
G2, 24 hours



GPS Only, Elevation Mask 25°



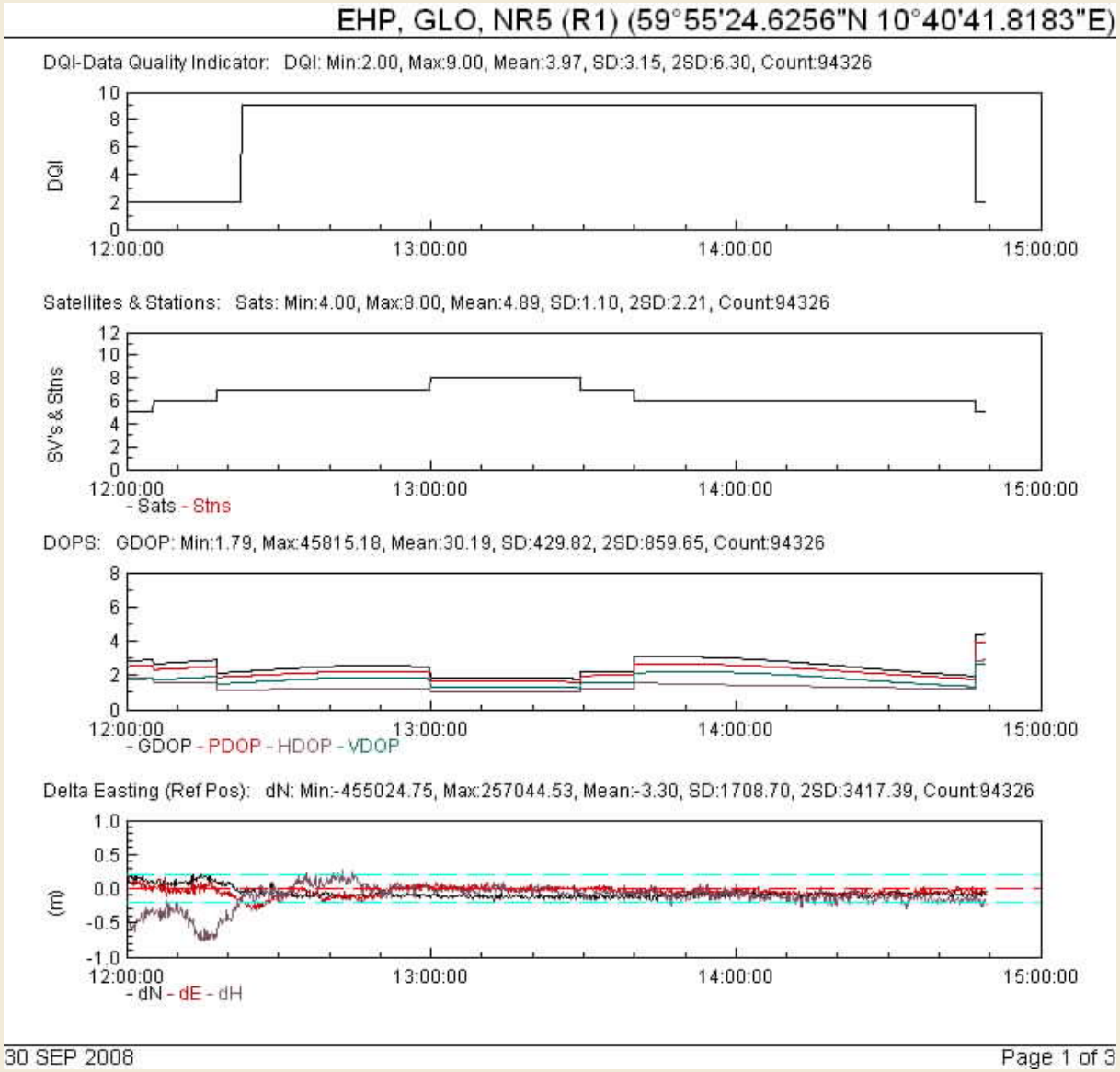
GPS & GLONASS, Elevation Mask 25°



GLONASS Only Coverage

During periods with enough GLONASS satellites, the solution is at the decimetre level using only GLONASS satellites.

dN = North error
dE = East Error
dH = Height error



What does the Future have in Store ?

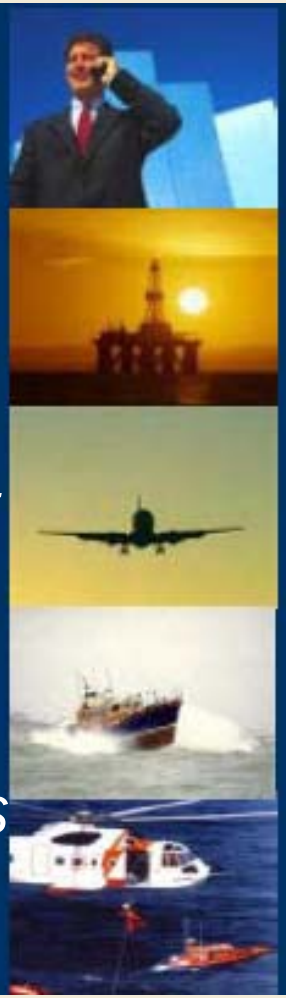
- ***Open Access***
  - Free to air; Mass market; Simple positioning
    (L1 single frequency: 15m H, 35m V, dual frequency: 4m H, 8 m V)
- ***Commercial***
  - Encrypted; High accuracy; Guaranteed service
- ***Safety of Life***
  - Unencrypted; Integrity; Authentication of signal
    (12 m HAL, 20 m VAL, others service level available)
- ***Search and Rescue***
  - Near real-time; Precise; Return link feasible
- ***Public Regulated***
  - Encrypted; Integrity; Continuous availability

OS

CS

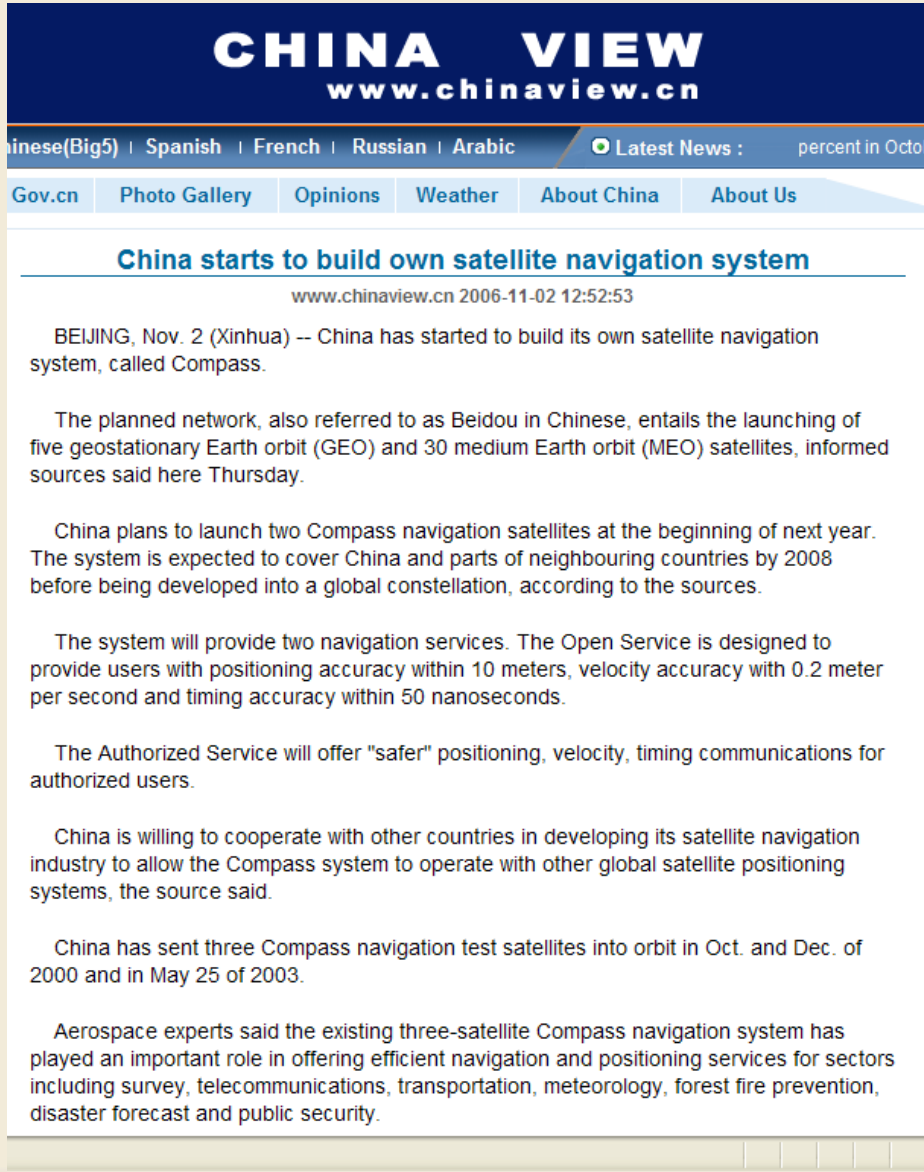
SOL

PRS



COMPASS

- China has filed for frequencies at ITU (International Telecommunications Union)
- 27 Satellites MEO, 21500 km, 55 deg
- 5 Satellites in Geostationary Orbit, 35786 km
- 3 Satellites Inclined Geostationary Orbit, 35786 km, 55 deg
- Similar frequencies as Galileo
- 10 meter accuracy
- Start launching two satellites 2008 (Geostationary)
- Continuation of the military ”Beidou”



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China starts to build own satellite navigation system

www.chinaview.cn 2006-11-02 12:52:53

BEIJING, Nov. 2 (Xinhua) -- China has started to build its own satellite navigation system, called Compass.

The planned network, also referred to as Beidou in Chinese, entails the launching of five geostationary Earth orbit (GEO) and 30 medium Earth orbit (MEO) satellites, informed sources said here Thursday.

China plans to launch two Compass navigation satellites at the beginning of next year. The system is expected to cover China and parts of neighbouring countries by 2008 before being developed into a global constellation, according to the sources.

The system will provide two navigation services. The Open Service is designed to provide users with positioning accuracy within 10 meters, velocity accuracy with 0.2 meter per second and timing accuracy within 50 nanoseconds.

The Authorized Service will offer "safer" positioning, velocity, timing communications for authorized users.

China is willing to cooperate with other countries in developing its satellite navigation industry to allow the Compass system to operate with other global satellite positioning systems, the source said.

China has sent three Compass navigation test satellites into orbit in Oct. and Dec. of 2000 and in May 25 of 2003.

Aerospace experts said the existing three-satellite Compass navigation system has played an important role in offering efficient navigation and positioning services for sectors including survey, telecommunications, transportation, meteorology, forest fire prevention, disaster forecast and public security.

Conclusions

- All elements of G2 developed and implemented by Fugro
- Uses correction data from Fugro's proprietary reference station network, both GPS and GLONASS.
- 10 cm accuracy (95%) almost independent of location.
- Improved Performance with Multiple GNSS
  - Independence
  - Availability
  - Reliability
  - Accuracy
- Within a few years up 120 GNSS satellites could be available for navigation and positioning.

Questions ?