Advantages of using GNSS for positioning in DP applications

Arvid Svenni, Fugro Seastar AS, Norway

Presented at FFU seminar, Stavanger, 25-Jan 2007

Global Navigation Satellite Systems, GNSS

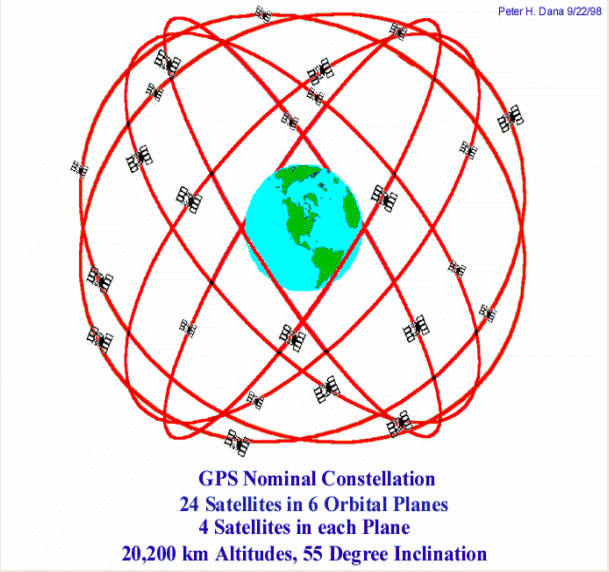
- Current status and outlook for Global Navigation Satellite Services:

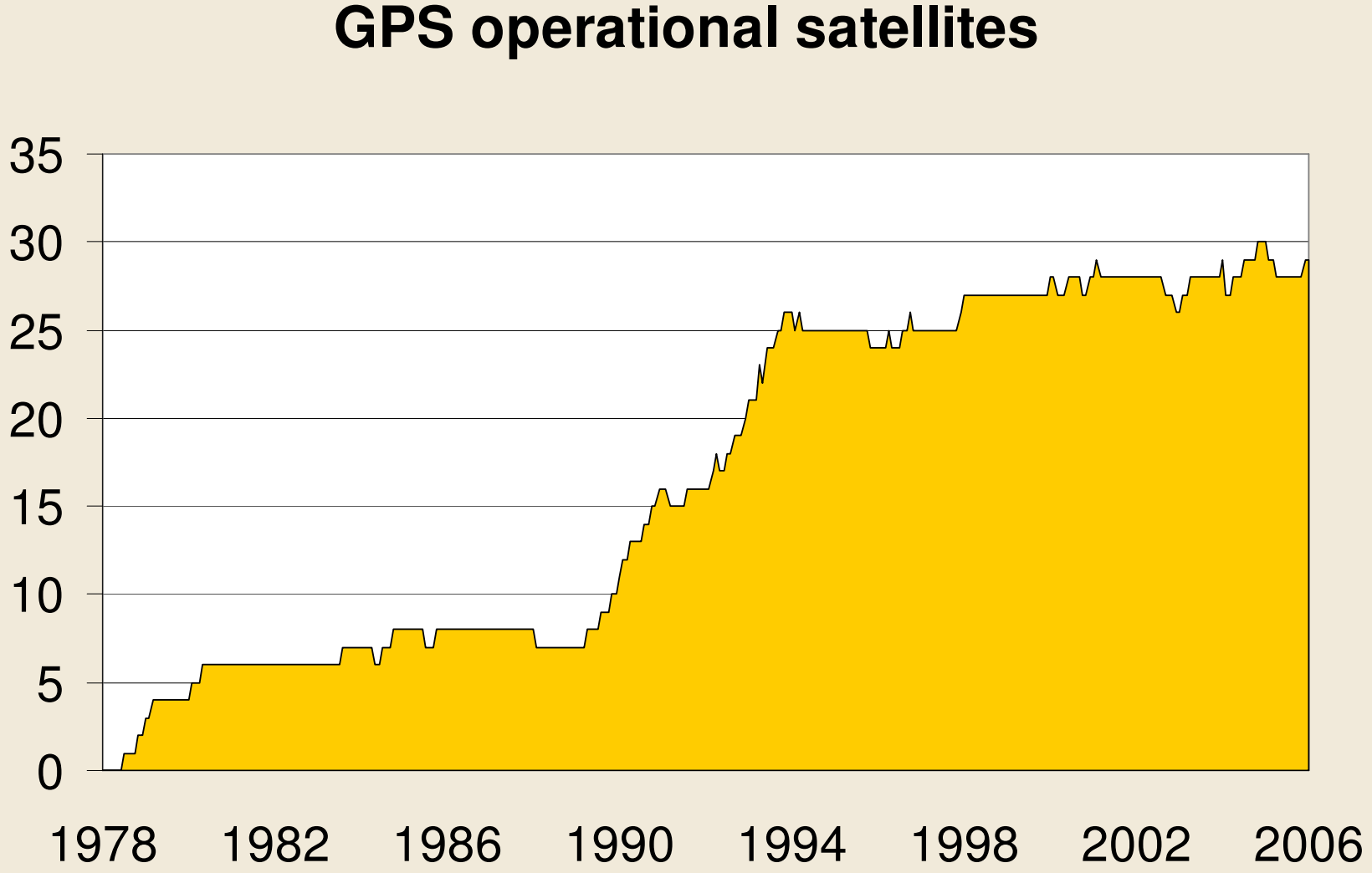
- Satellites
  - About 50 navigation satellites are available today (31 GPS and 16 GLONASS)
  - 80 satellites in 5 years
- Frequencies
  - 2 frequencies are available today (One being tracked codeless with reduced tracking margin)
  - 3 frequencies in 5-8 years time (will be available with full code tracking)
- Interoperability
  - The GNSS operators are coordinated to ensure compatibility/interoperability (frequencies, modulation codes, coordinate reference frames, timing reference)

GPS Status

- 31 Operational Satellites
- Global GPS availability was better than 99.99% in 2005
- GPS Accuracy 5-10 m 95%

- GPS IIR-14(M)
- New civilian signal on L2
- launched 25 Sep 2005



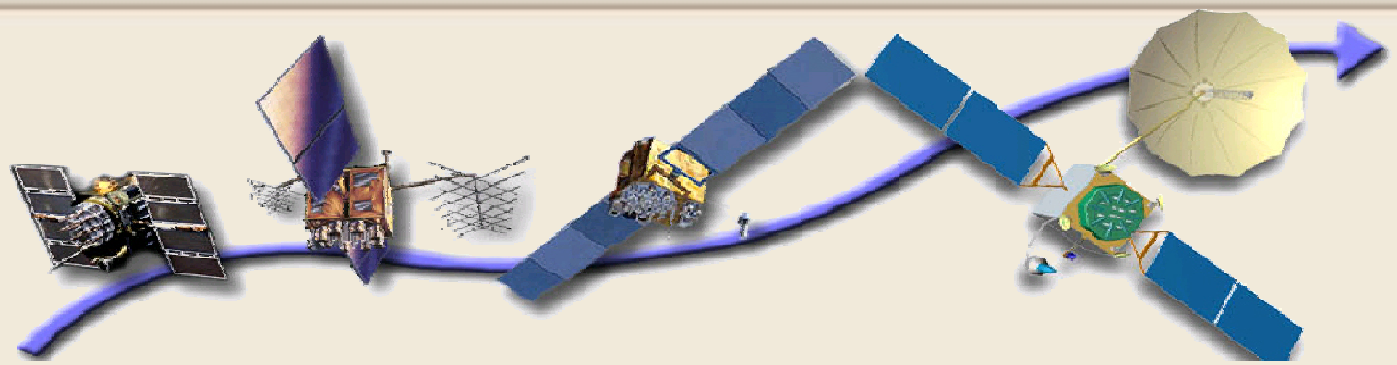

GPS operational satellites
35
30
25
20
15
10
5
0
1978
1982
1986
1990
1994
1998
2002
2006

GPS Status 6 Dec. 2006

Plane	SVN	PRN	NORAD	Type SC	Launch date	Input date	Outage date	Active life (months)	Notes
A	1	9	22700	II-A	26.06.93	20.07.93		159.9	
	2	31	29486	IIR-M	25.09.06	13.10.06		1.8	
	3	8	25030	II-A	06.11.97	18.12.97		107.7	
	4	27	22108	II-A	09.09.92	30.09.92		169.7	
	5	25	21890	II-A	23.02.92	24.03.92		173.9	
B	1	16	27663	II-R	29.01.03	18.02.03		45.4	
	2	30	24320	II-A	12.09.96	01.10.96		121.4	
	3	28	26407	II-R	16.07.00	17.08.00		75.7	
	4	5	22779	II-A	30.08.93	28.09.93		157.8	
C	1	6	23027	II-A	10.03.94	28.03.94		151.7	
	2	3	23833	II-A	28.03.96	09.04.96		127.0	
	3	19	28190	II-R	20.03.04	05.04.04		32.0	
	4	17	28874	IIR-M	26.09.05	13.11.05		11.5	
	5	7	22657	II-A	13.05.93	12.06.93		161.5	
D	1	2	28474	II-R	06.11.04	22.11.04		24.5	
	2	11	25933	II-R	07.10.99	03.01.00		83.1	
	3	21	27704	II-R	31.03.03	12.04.03		43.7	
	4	4	22877	II-A	26.10.93	22.11.93		156.5	
	5	15	20830	II	01.10.90	15.10.90	21.08.06	190.3	Temporarily is switched of
	6	24	21552	II-A	04.07.91	30.08.91		183.3	
E	1	20	26360	II-R	11.05.00	01.06.00		78.1	
	2	22	28129	II-R	21.12.03	12.01.04		34.8	
	3	10	23953	II-A	16.07.96	15.08.96		123.7	
	4	18	26690	II-R	30.01.01	15.02.01		69.6	
F	1	14	26605	II-R	10.11.00	10.12.00		71.9	
	2	26	22014	II-A	07.07.92	23.07.92		172.4	
	3	13	24876	II-R	23.07.97	31.01.98		106.1	
	4	23	28362	II-R	23.06.04	09.07.04		28.8	
	5	29	22275	II-A	18.12.92	05.01.93		166.4	

Oldest satellite
from 1991

GPS Modernization Program



Increasing System Capabilities ◆ Increasing Defense / Civil Benefit

Block IIA/IIR

Basic GPS

- Standard Service
  - – Single frequency (L1)
  - – Coarse acquisition (C/A) code navigation
- Precise Service
  - – Y-Code (L1Y & L2Y)
  - – Y-Code navigation

Block IIR-M, IIF

IIR-M: IIA/IIR capabilities plus

- **2nd civil signal (L2C)**
- M-Code (L1M & L2M)

2005-2012

IIF: IIR-M capability plus

- **3rd civil signal (L5)**
- Anti-jam flex power

2008-2015

Block III

- Backward compatibility
- **4th civil signal (L1C)**
- Increased accuracy
- Increased anti-jam power
- Assured availability
- Navigation surety
- Controlled integrity
- Increased security
- System survivability

2013-2021

National Space-Based PNT Coordination Office, USA

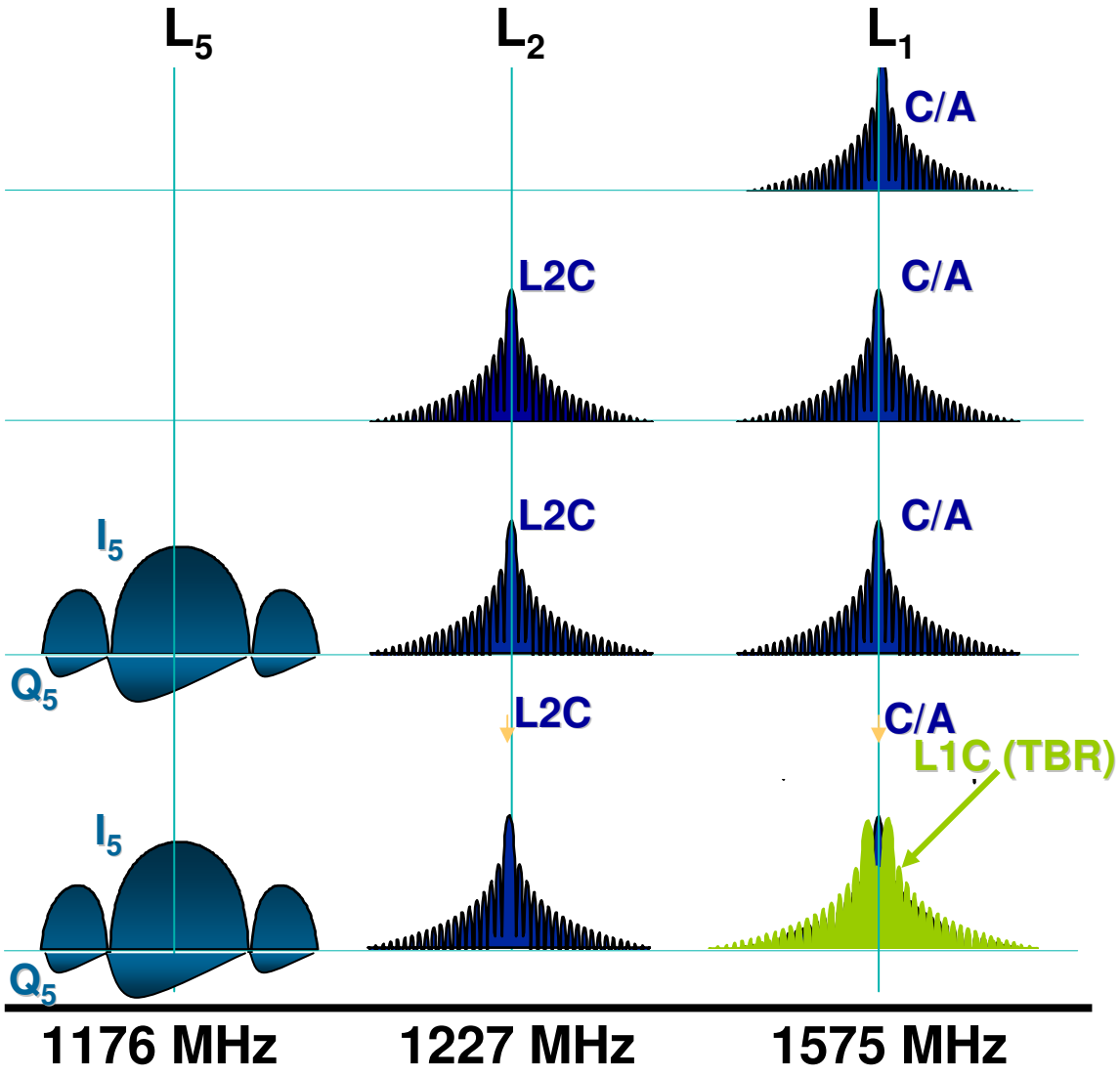
GPS Civil Signals

1st Civil
Block II/IIA/IIR

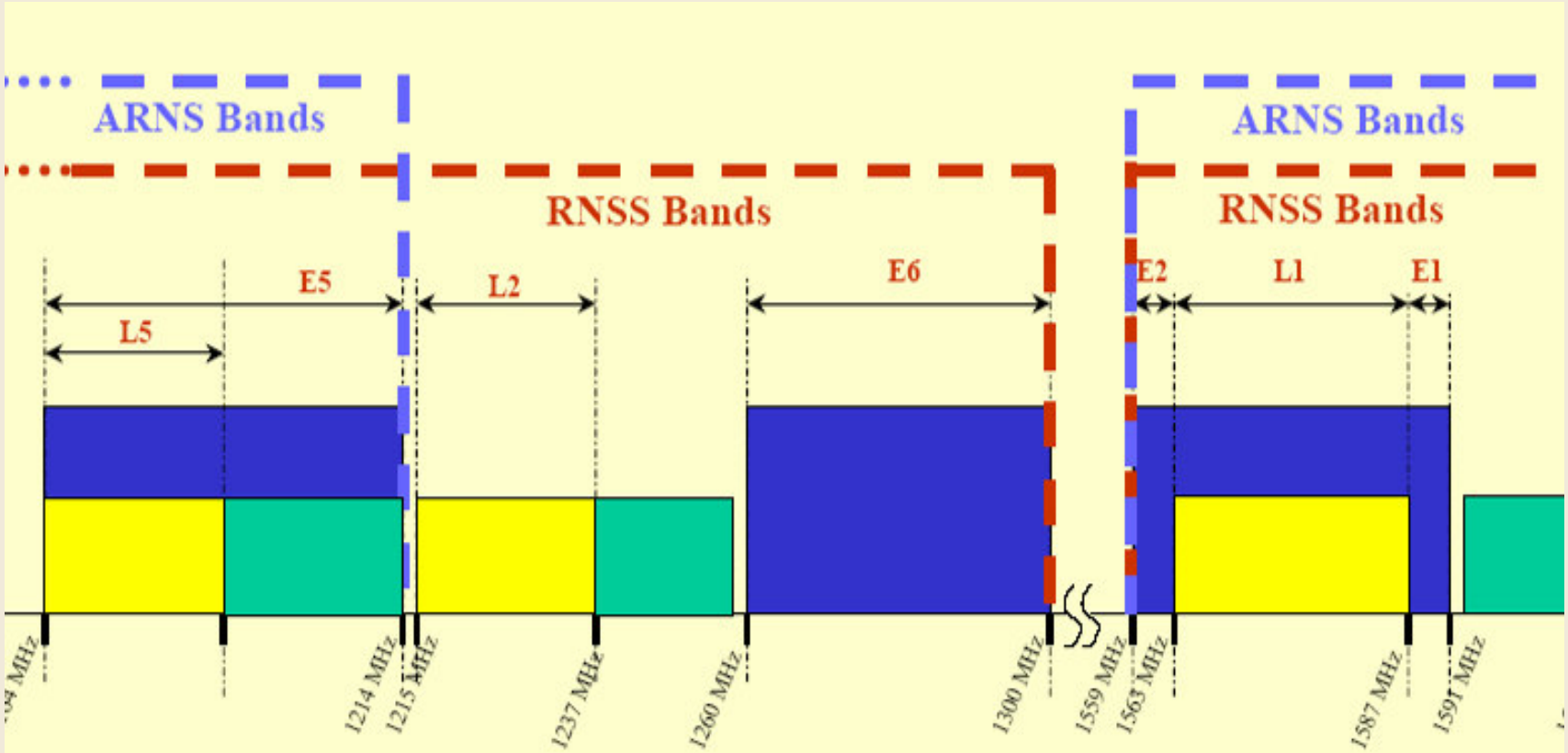
2nd Civil
Block IIR-M

3rd Civil
Block IIF

4th Civil
Block III



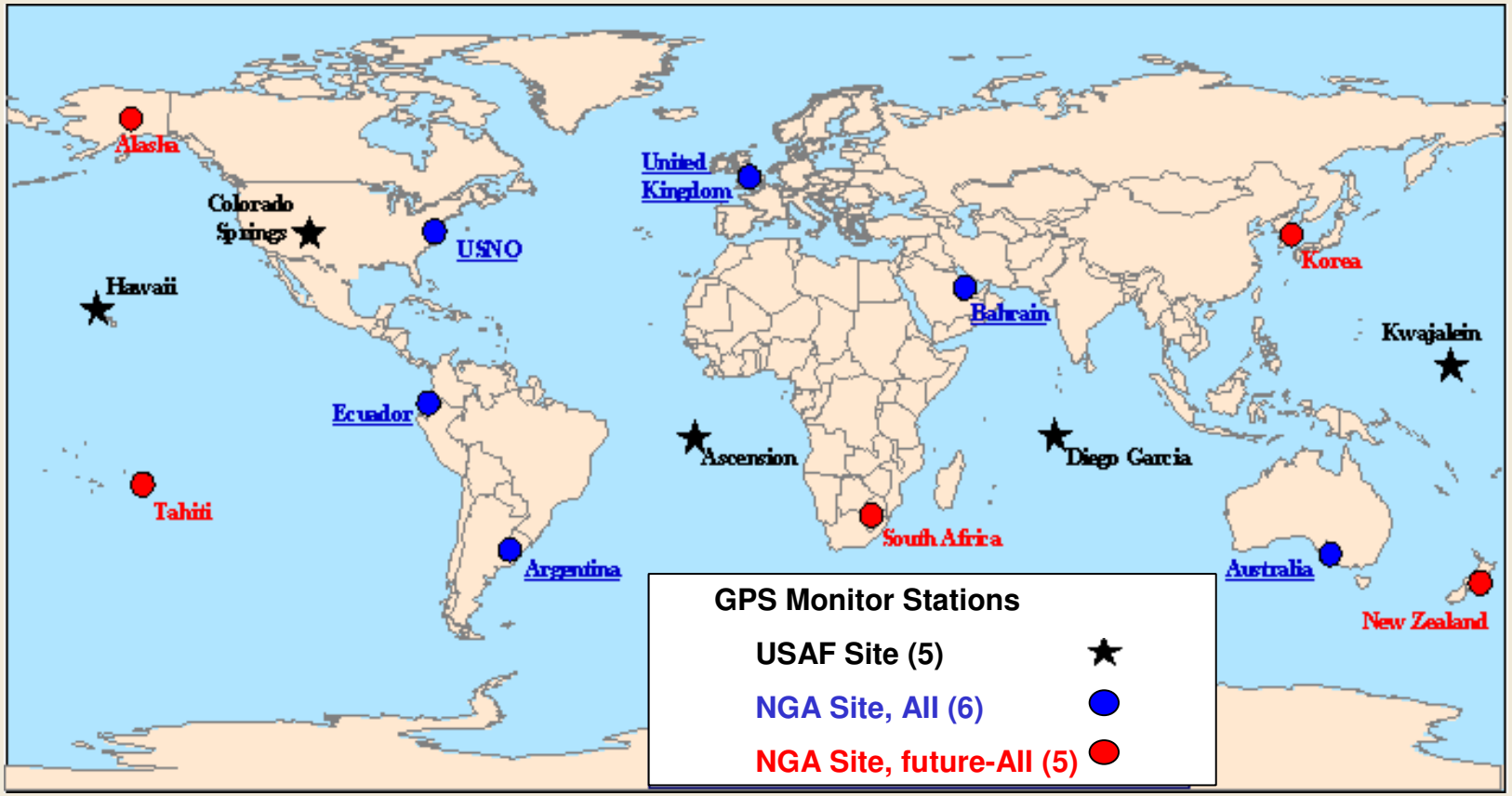
GALILEO/GPS/GLONASS FREQUENCY BANDS



RNSS = Radio Navigation Satellite Service
ARNS = Aeronautical Radio Navigation Service

Galileo, Status and Test User Receiver,
Martin Hollreiser, Navitec, Estec, 8 Dec 2004

USAF & NGA MONITOR STATIONS

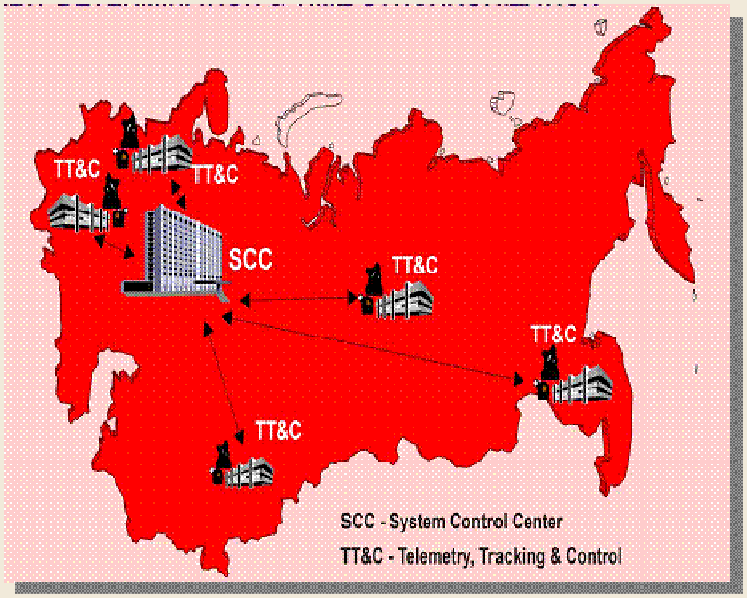


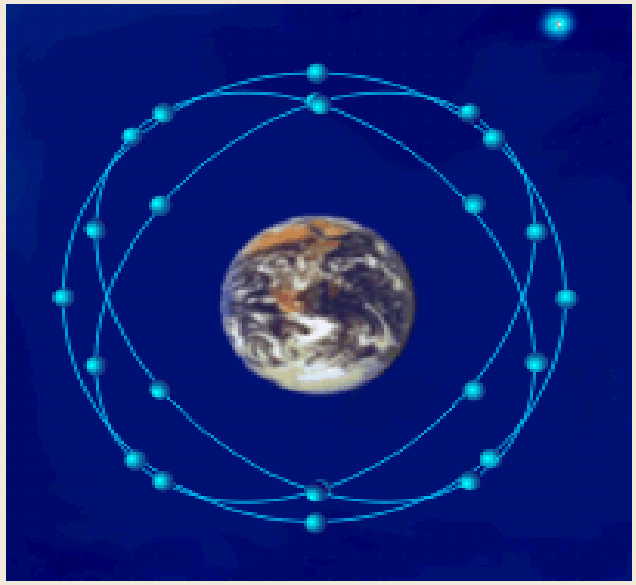
- In Sept 05, NGA sites (Core 6) was added to AF MS sites
- By CY06, 5 more NGA sites will be added to L-AII

Accuracy Improvement Initiative (AII) NGA: National Geospatial-Intelligence Agency

GLONASS, Russian Satellite Navigation System

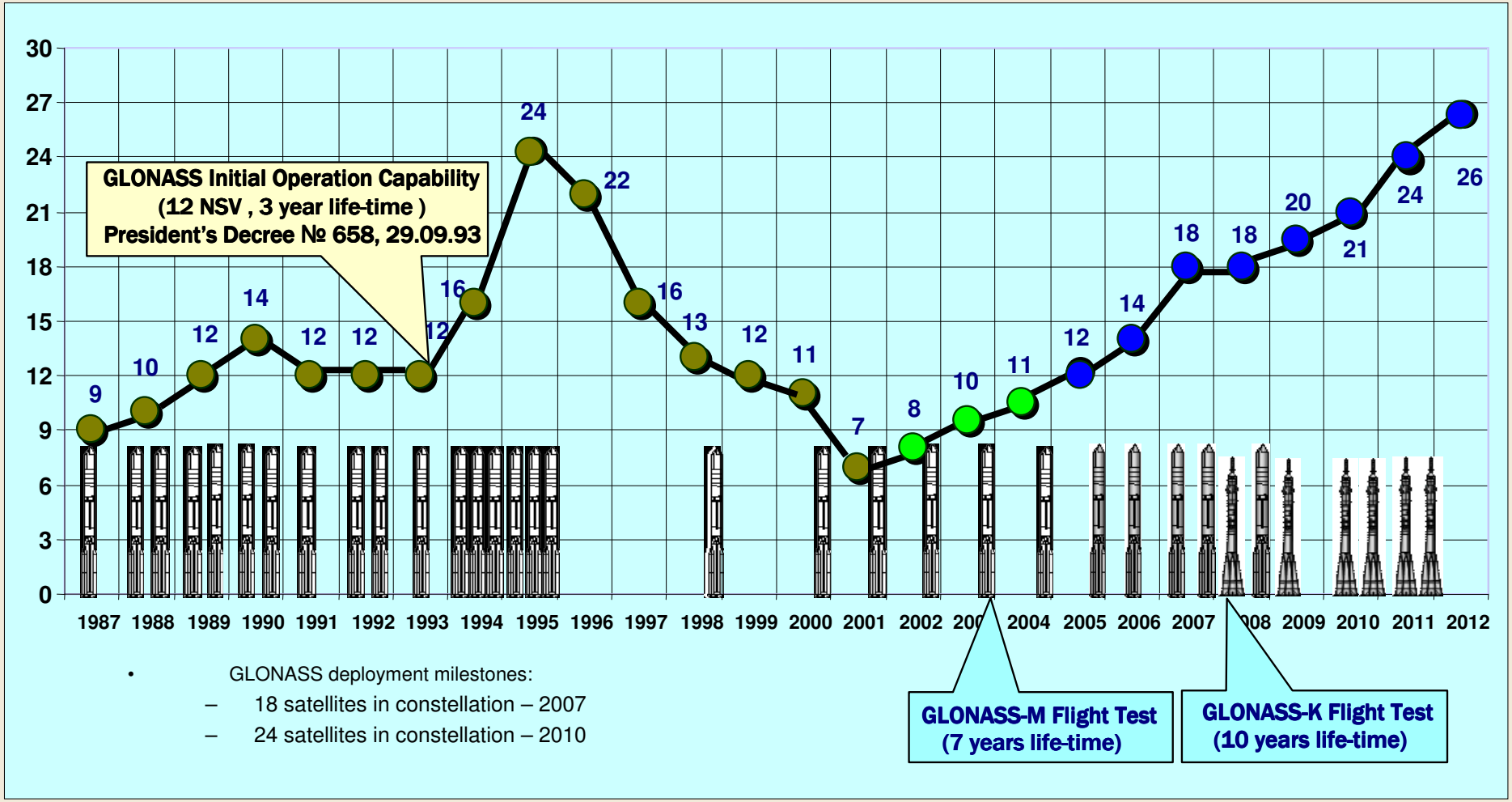
- Constellation: 24 satellites, 3 orbital planes
- Orbital altitude: 19100 km, Inclination: 64.8°
- Period of revolution: 11h 15m (repeat ground track in 17 days)
- Frequency Division Multiple Access (FDMA)





GLONASS STATUS AND PLANS, Veniamin Malyshev, Moscow Aviation Institute
Presented at Nordic Satnav User Conference, 29-30 Nov 2005, www.nornav.org

GLONASS Constellation Deployment, original plan



- GLONASS deployment milestones:
  - 18 satellites in constellation – 2007
  - 24 satellites in constellation – 2010

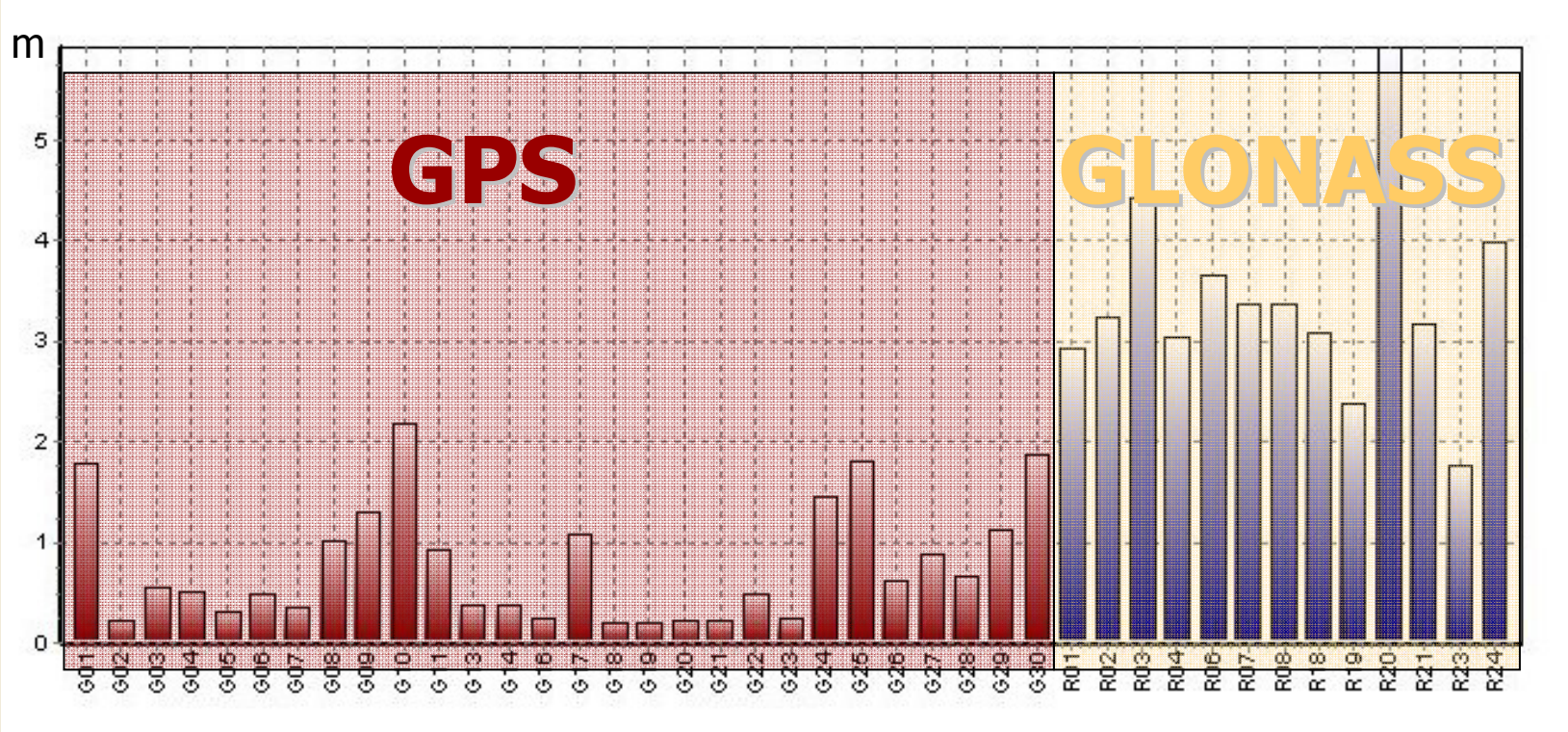
GLONASS Constellation Status

GLONASS constellation status for 21.01.07 under the analysis of the almanac accepted in IANC 20:00 21.01.07 (UTC)

Plane	Slot	Frequency Channel	GLONASS Number	Cosmos Number	Launch date	Input date	Outage date	Active life (months)	Notes
I	1	7	796	2411	26.12.04	06.02.05	17.01.07	22.3	Temporarily is switched off
	2	1	794	2402	10.12.03	02.02.04		35.4	
	3	12	789	2381	01.12.01	04.01.02	24.11.06	56.5	Temporarily is switched off
	4	6	795	2403	10.12.03	29.01.04		35.6	
	5	7	711	2382	01.12.01	13.02.03	09.07.06	36.1	Temporarily is switched off
	6	1	701	2404	10.12.03	08.12.04	07.01.07	20.3	Temporarily is switched off
	7	4	712	2413	26.12.04	07.10.05		13.9	
	8	6	797	2412	26.12.04	06.02.05		22.6	
II									
	10	4	717	2426	25.12.06				Commissioning Phase
	14	4	715	2424	25.12.06				Commissioning Phase
	15	0	716	2425	25.12.06				Commissioning Phase
III	17	5	787	2375	13.10.00	04.11.00	12.09.06	68.7	Temporarily is switched off
	18	10	783	2374	13.10.00	05.01.01	21.01.07	64.1	Temporarily is switched off
	19	3	798	2417	25.12.05	22.01.06		11.9	
	20	11	793	2396	25.12.02	31.01.03	23.09.06	41.7	Temporarily is switched off
	21	5	792	2395	25.12.02	31.01.03		46.2	
	22	10	791	2394	25.12.02	21.01.03	01.01.07	46.0	Temporarily is switched off
	23	3	714	2419	25.12.05	31.08.06		3.6	
	24	2	713	2418	25.12.05	31.08.06		4.1	

http://www.glonass-ianc.rsa.ru/pls/htmldb/f?p=202:1:14868901511050409234

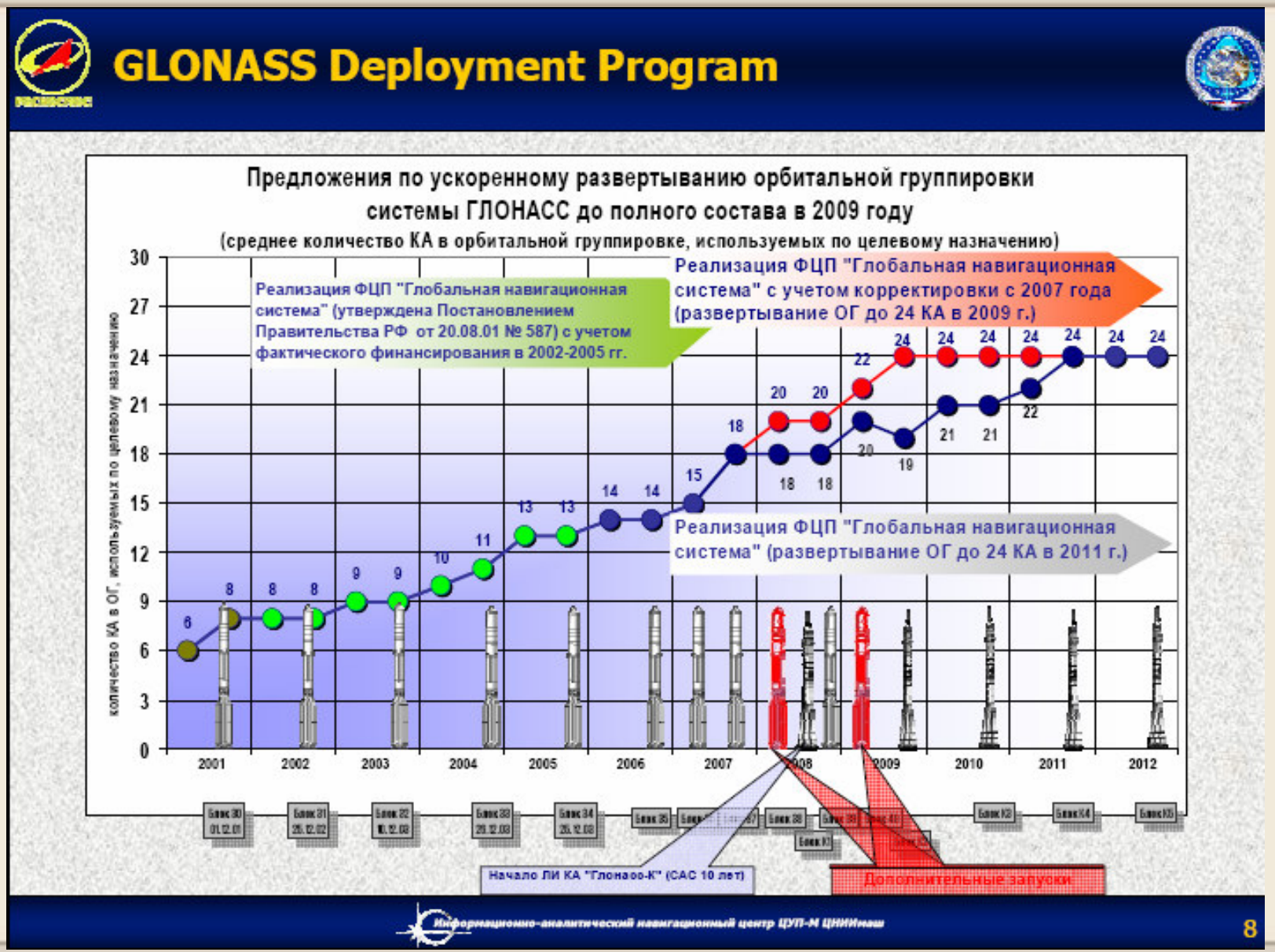
SISRE monitoring (22.09.2006)



GPS satellite number

GLONASS satellite number

GLONASS Constellation Deployment, Updated



http://www.munich-satellite-navigation-summit.org/Program.htm

GLONASS

- Three more GLONASS-M spacecraft were launched on Dec. 25, 2006
- On August 30, 2006, RIA Novosti news agency quoted Minister of Defense Sergei Ivanov promising a full deployment of a 24-satellite GLONASS constellation by 2010.

http://www.russianspaceweb.com/uragan.html

http://en.rian.ru/russia/20061226/57810801.html

- Starting on Jan. 1, 2007, all restrictions on the purchase and use of GPS receivers was lifted all over Russia

http://www.upi.com/SecurityTerrorism/view.php?StoryID=20061220-110725-1576r

RUSSIAN NEWS & INFORMATION AGENCY NOVOSTI

- Gazprom: today Russia, tomorrow the w
- Russian companies broke no internationa
- Poland says Russian oil stops coming via
- U.S. asks Russia to increase air traffic alor

Russia

Russia launches three Glonass satellites

09:48 | 26/12/2006

MOSCOW, December 26 (RIA Novosti) - Russia has expanded its global navigation satellite system (Glonass) with three satellites, a spokesman for the Russian Federal Space Agency (Roscosmos) said Tuesday.

A Proton-K rocket carrying three modernized Glonass-M satellites lifted off at 23:18 Moscow time (8:18 p.m. GMT) Monday from the Baikonur space center in Kazakhstan. The satellites were put into orbit early Tuesday.

Glonass, a Russian version of the U.S. Global Positioning System (GPS), is designed for both military and civilian purposes, and allows users to identify their positions in real time. It can also be used in geological prospecting.

President Vladimir Putin ordered in December 2005 that the system be ready by 2008 and in March this year Defense Minister Sergei Ivanov said Glonass will be available to domestic consumers for military as well for civilian purposes by the end of 2007.

Roscosmos head Anatoly Perminov said earlier Russia is in talks with the United States and the European Space Agency to prepare agreements on the use of Glonass jointly with GPS and Galileo satellite navigation systems.

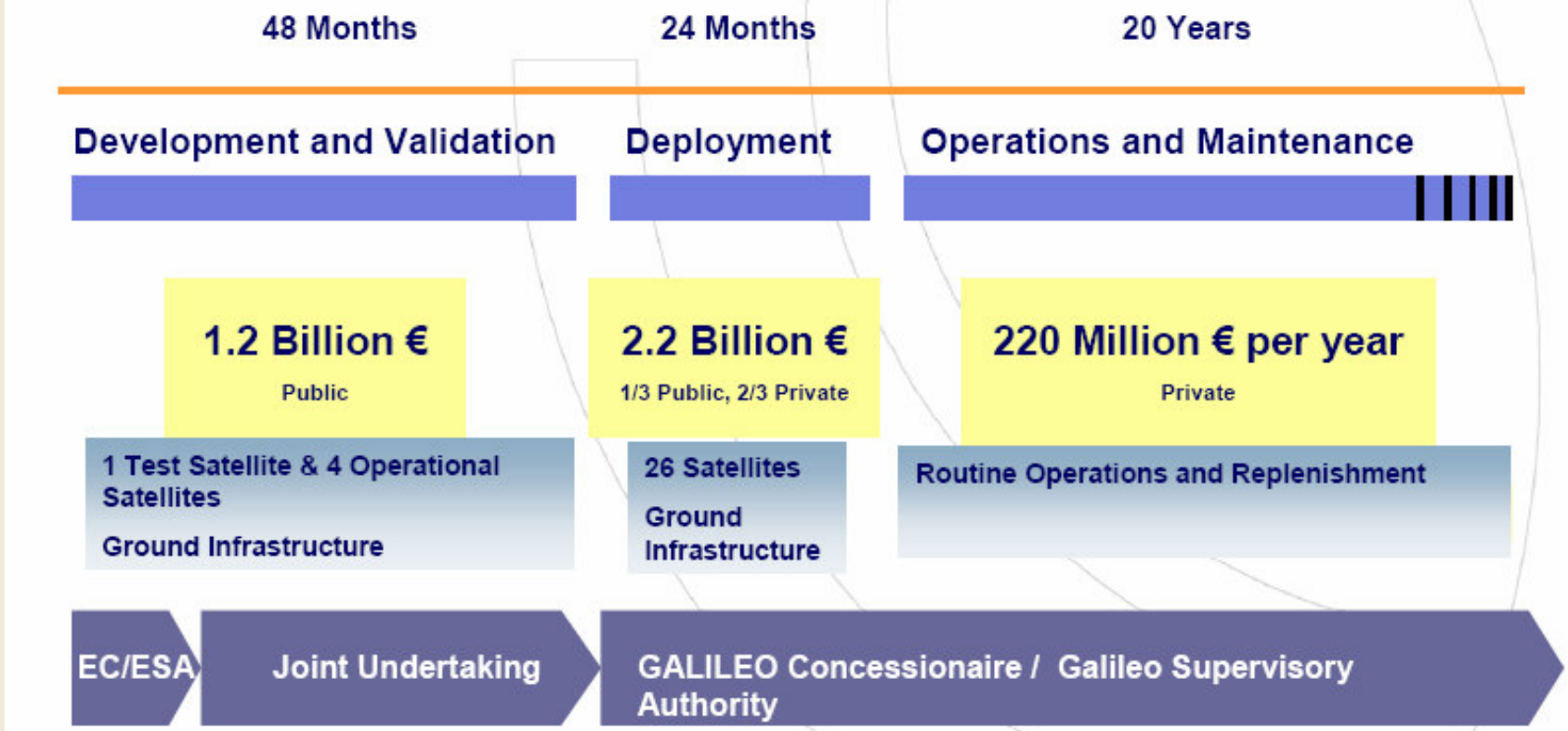
The agency plans to have 18 satellites in orbit by late 2007 or early 2008, and a full orbital group of 24 satellites by the end of 2009, he said.

In November Russian Defense Minister Sergei Ivanov said Russia will lift all precision restrictions, from the start of 2007, in the use of Glonass to enable accurate and unlimited commercial use of the military-controlled global positioning system. Current restrictions limit the accuracy for civilian users of Glonass to 30 meters.

The first launch under the Glonass program took place October 12, 1982, but the system was only formally launched September 24, 1993.

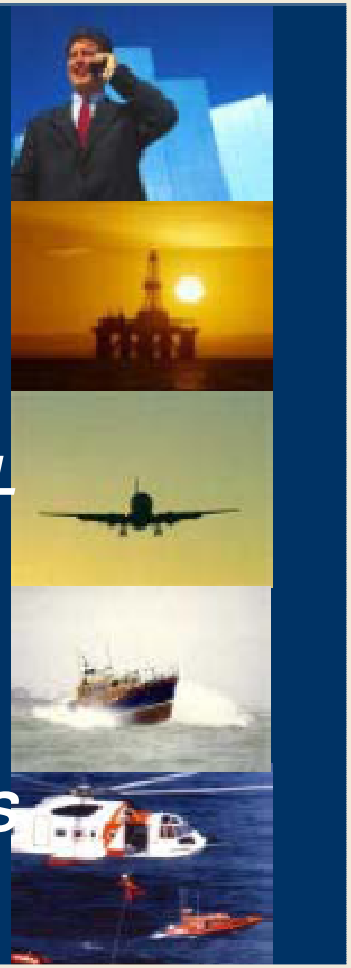
GALILEO, European Satellite Navigation System

Overall Schedule



GALILEO Services Definition

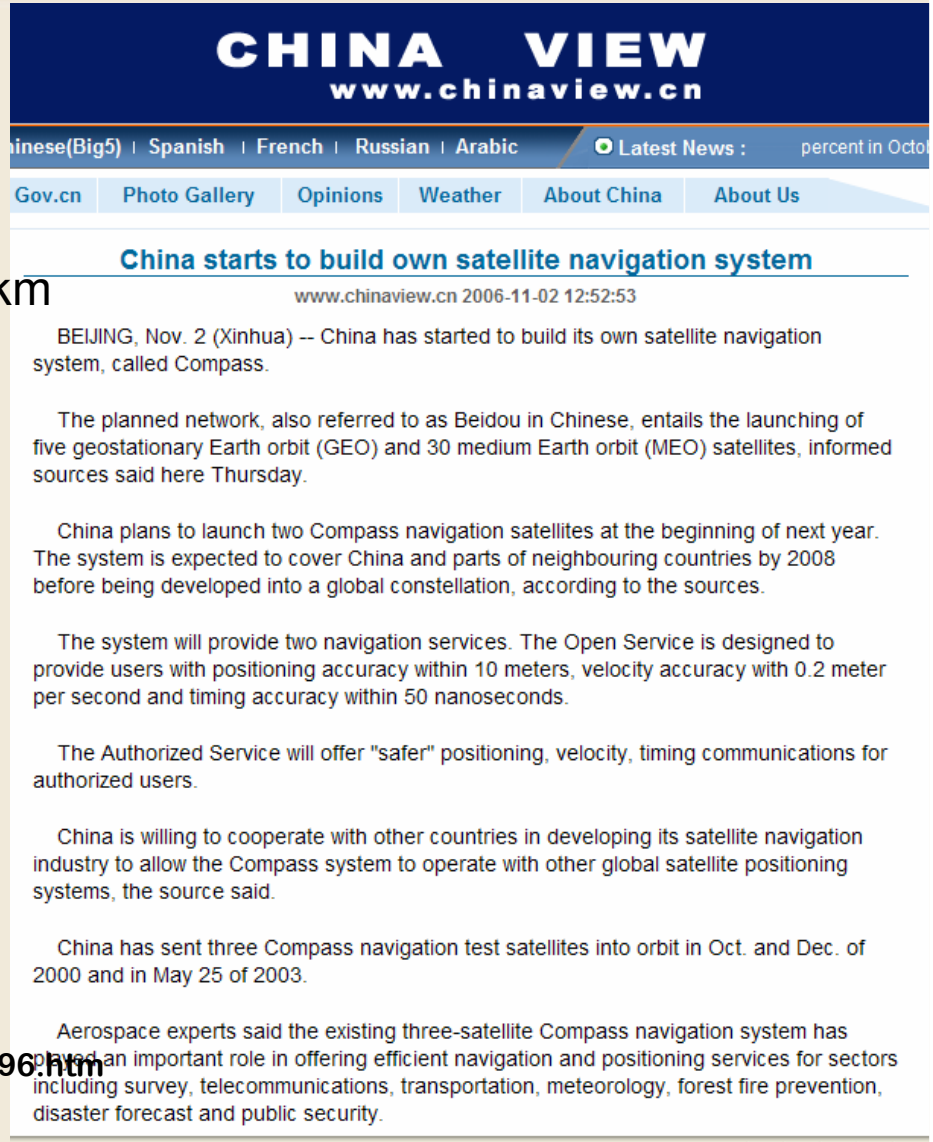
- ***Open Access***
  - Free to air; Mass market; Simple positioning
    (L1 single frequency: 15m H, 35m V, dual frequency: 4m H, 8 m V)
- ***Commercial***
  - Encrypted; High accuracy; Guaranteed service
- ***Safety of Life***
  - Unencrypted; Integrity; Authentication of signal
    (12 m HAL, 20 m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



Galileo, Status and Test User Receiver,
Martin Hollreiser, Navitec, Estec, 8 Dec 2004

COMPASS, Chinese Satellite Navigation System

- 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)



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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.

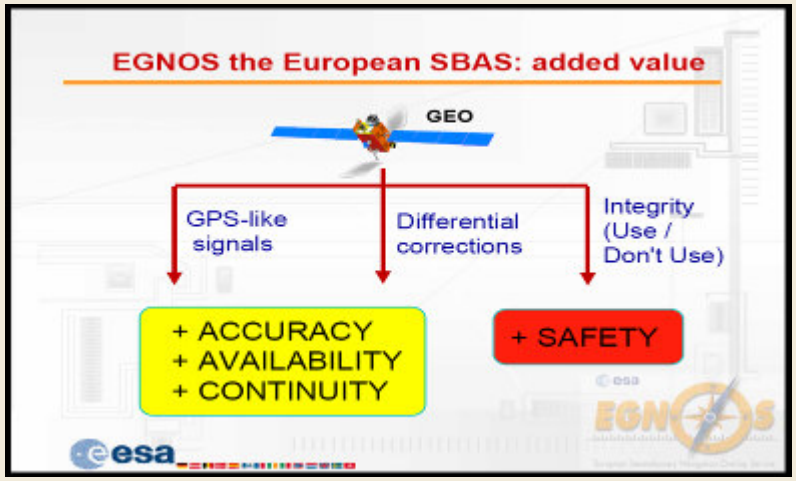
China has sent three Compass navigation test satellites into orbit in Oct. and Dec. of 2000 and in May 25 of 2003.

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.

http://news3.xinhuanet.com/english/2006-11/02/content_5280896.htm
http://www.newscientisttech.com/article.ns?id=dn10472
http://www.itu.int/jive/servlet/JiveServlet/download/432-1165-287168-650/COMPASS-up.doc

Space Based Augmentation Services, SBAS

- WAAS
  - Wide Area Augmentation Service, USA. Operational 2003
- EGNOS
  - European Geostationary Navigation Overlay Service, 2006-2007



- MSAS
  - MTSAT (Multi functional Transport Satellites) Satellite based Augmentation Systems (MSAS), Japanese SBAS, operational 2008
- GAGAN
  - GPS-Aided Geo Augmented Navigation, Indian SBAS, operational 2008

GNSS Receiver Availability

- Some Commercial GPS/GLONASS receivers have been available for more than 10 years.
- In 2006 all major receiver manufacturers have launched a new generation of receivers:
  - Combined receivers for two or more GNSS systems
    - Some prepared for Galileo
  - Support new civilian signals (L2C, L5)
- Multiple satellite system implementations in the new generation receivers prompted by the revitalization of GLONASS
- This added availability of receivers very important for acceptance of use of combined systems.

Receiver Manufacturers and GLONASS Capability

PRESS RELEASE

Topcon Positioning Systems, Inc.
7400 National Drive
Livermore, CA 94551
800-443-4567

Topcon opens G3 door to the future

Livermore, California, January 17, 2006–

G3.

Simple name.

Revolutionary technology.

Topcon Positioning Systems (TPS) announces the Paradigm G3 chip, a new technology that sets the standard for the future of satellite positioning. Satellite positioning systems are widely used for land surveying and machine control tasks. To operate, these systems need to receive a minimum of five satellites at all times. When the minimum number of satellites is not available due to obstructions - trees, buildings, or steep slopes -- reception is interrupted, creating costly downtime on the job site.

Topcon's GPS+ GLONASS technology virtually eliminated satellite access problems. The new Topcon G3 technology takes it a step further by adding the soon-to-be-available European Union Galileo satellite constellation, which will eventually have a total of more than 30 satellites. The G3 chip with its patented Universal Signal Tracking capabilities has 72 universal channels that can receive signals from up to 36 satellites simultaneously.

The advantages of Topcon's Paradigm G3 are numerous and include:

- Tracks all signals from all available satellite positioning systems now and in the future to provide seamless positioning information.
- Patented new generation firmware is designed to dynamically adjust to satellites with best signal strength.
- High rate signal sampling delivers industry leading performance and accuracy.
- Streamlined chip profile - 75 percent smaller than current chips, enabling small, lighter receiver design.
- Unmatched tracking capabilities in difficult environments reduce signal degradation.

http://www.topconpositioning.com/news/PPR/pr_NetG3.html

Topcon and Thales have had GLONASS Capability many years.
Topcon announces new receiver, also Galileo compatible.

Receiver Manufacturers and GLONASS Capability

News Releases

NovAtel Inc. Announces GPS+GLONASS Capability on its New OEMV Family of Receivers

FOR IMMEDIATE RELEASE

Contact: Farlin Halsey (403) 295-4970
Investor Contact: Sonia Ross (403) 295-4532

(Calgary, Alberta, Canada, February 6, 2006) - NovAtel Inc. (NASDAQ: NGPS), a precise positioning technology company, today announced that its new line of OEMV Global Positioning System (GPS) receivers will also be capable of tracking satellites from the growing Global Navigation Satellite System (GLONASS) constellation. Initial releases of the OEMV-2 and OEMV-3 models are expected to be available to customers by the end of March, as previously announced in September 2005, and will include dual-frequency GLONASS measurements as an option. Future releases will include full position and Real-time Kinematic (RTK) options as well as a GLONASS enabled, single-frequency OEMV-1 model.

http://www.novatel.com/about_us/news/20060206.htm

Novatel and Trimble add GLONASS capability for the first time (Announced within one day of each other)

Trimble Introduces Survey System and New Infrastructure Network Receiver with Added GNSS Support

Trimble R8 GNSS System and
Trimble NetR5 Reference Station Receiver Offer Greater Flexibility and
More Robust Signal Tracking

SUNNYVALE, Calif., Feb. 7, 2006 -- Trimble (NASDAQ:TRMB) today introduced two new products as part of its Connected Survey Site model-the Trimble® R8 GNSS system and Trimble NetR5™ reference station receiver with added Global Navigation Satellite System (GNSS) capabilities. The positioning products, with Trimble R-Track™ technology, support GPS L2C and L5 signals as well as GLONASS adding greater flexibility and more robust signal tracking to provide a seamless and streamlined workflow for all of the critical phases of surveying.

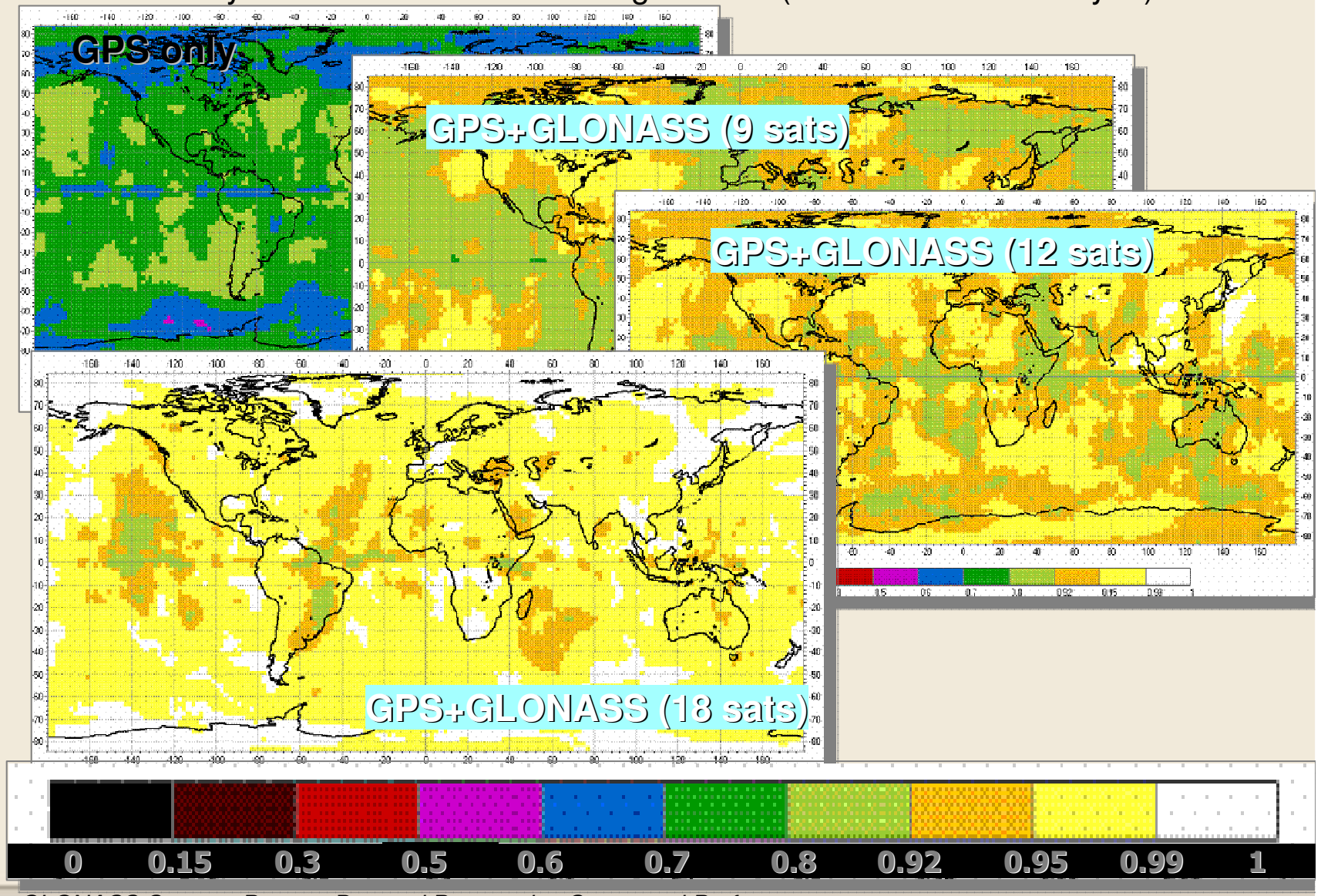
http://www.trimble.com/news/020706a.shtm

Improved Performance

- 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.
- Reliability
  - Increased redundancy of data (additional lines of position) will help to identify bad measurements
  - More resistant towards interference with more frequencies.
- Accuracy
  - Improved accuracy with more frequencies (ionospheric delay compensation) and satellites (improved geometry)
  - Improved convergence time in regional phase based decimeter level systems

Improved Availability, GPS plus GLONASS

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



GLONASS System: Present Day and Prospective Status and Performance, Sergey V. Averin, ENC-2006, Manchester

Grane Incident 6 May 2005

- Supply Vessel “Island Ranger” collided with Grane Platform during loading
  - Minor damage to Supply Vessel
- From the investigation:
  - The problems with the DGPS’s were caused by the position of the vessel close to the platform causing shielding of GPS satellites.
  - The vessel should not have operated on DP due to lack of positioning system redundancy
- Problems would have been mitigated with additional satellites providing safer operations.
- This is just one example one of many similar incidents.

 http://www.hydro.com/en/press_room/news/archive/2005_05/grane_en.html

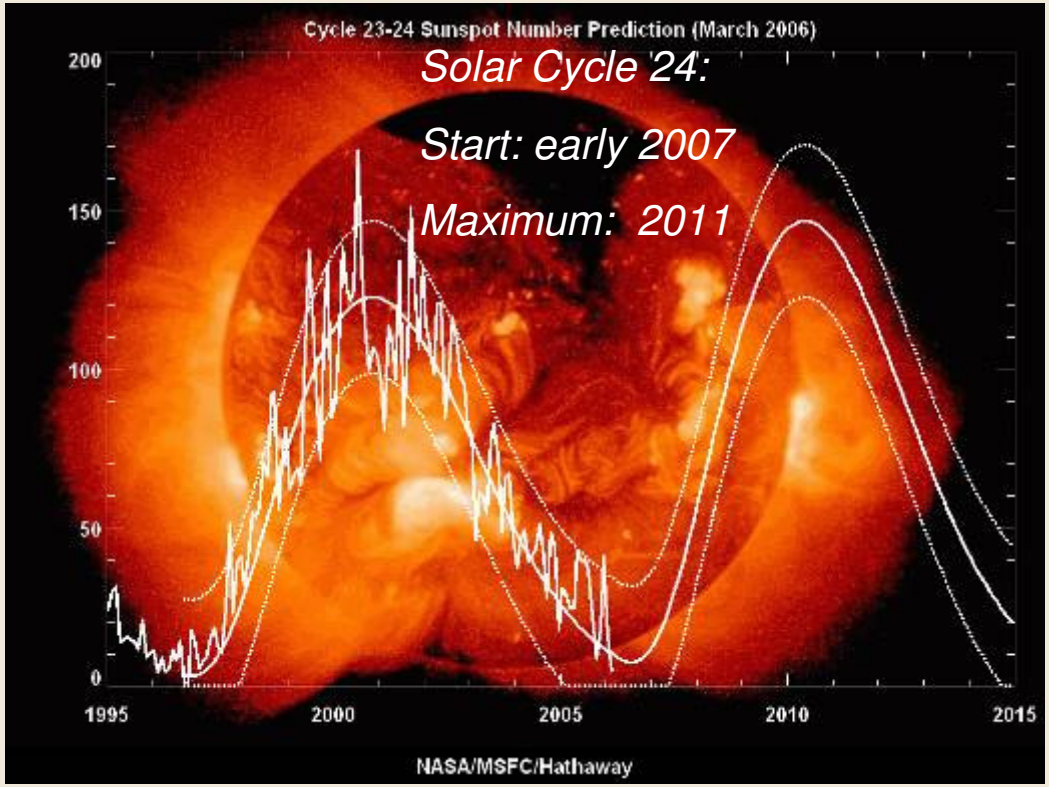
Solar Cycle 24

Ionospheric scintillations (tend to affect a part of the sky):

- Receiver looses lock
- Mitigated by additional satellites

Unpredictable ionospheric electron content:

- Delay in ranging measurement
- Mitigated by additional frequencies



- DP operations in equatorial regions where heavily affected during the previous solar cycle
- Petrobras specified use of GPS+GLONASS for certain operations in Brazil

http://www.nasa.gov/vision/universe/solarsystem/solar_cycle_graphics.html

Conclusions

- GPS
  - 31 Operational satellites
  - Block IIR with L2C, M-Code: 2005-2012
  - Block IIF with L5: 2008-2015
- GLONASS
  - 16 Operational satellites
  - 24 planned by 2009
- Galileo
  - Initial Orbit Validation (IOV) 2008-2009
  - Fully operational end 2011
- Improvements in Performance
  - Independence, Availability, Reliability, Accuracy
- Implications for DP
  - Independent Reference Systems, Availability in shaded areas, Improved performance during next solar cycle