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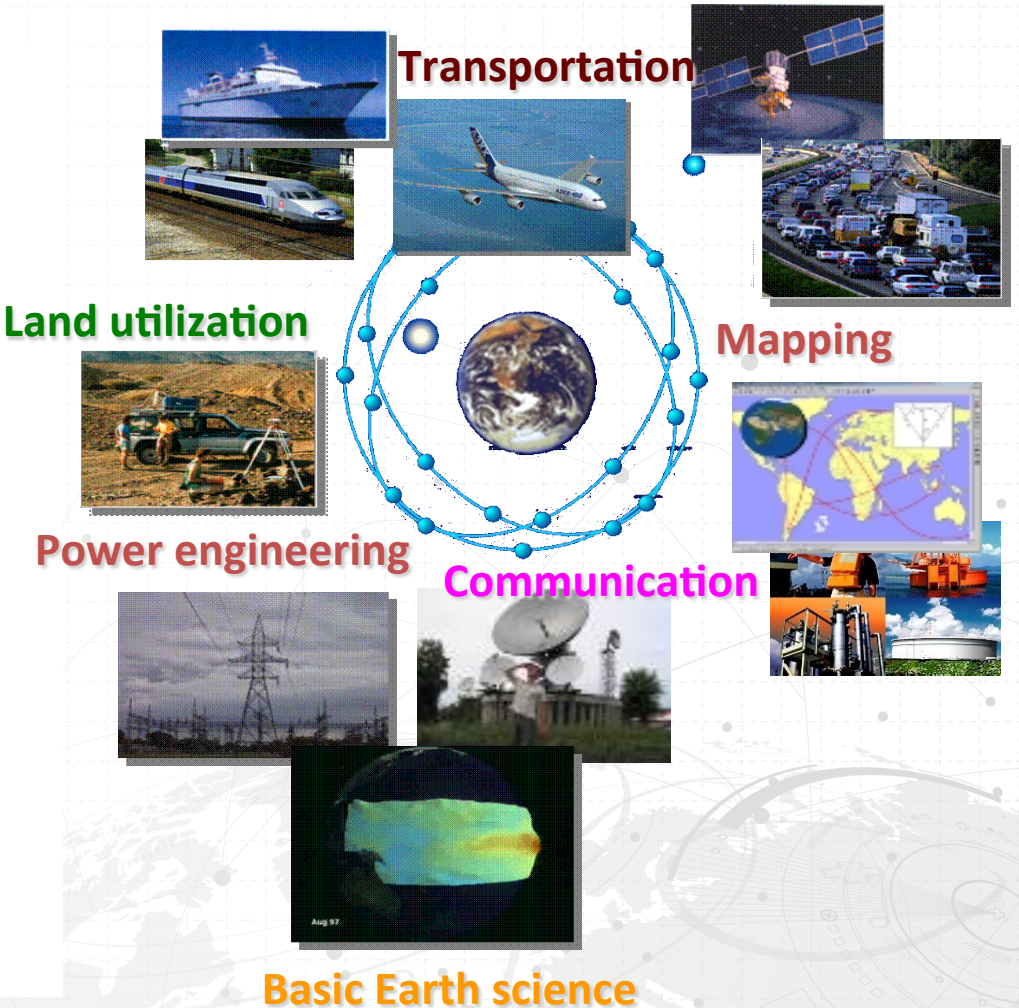
GNSS GLONASS Augmentation System-SDCM. Status and development

Satellite navigation applications

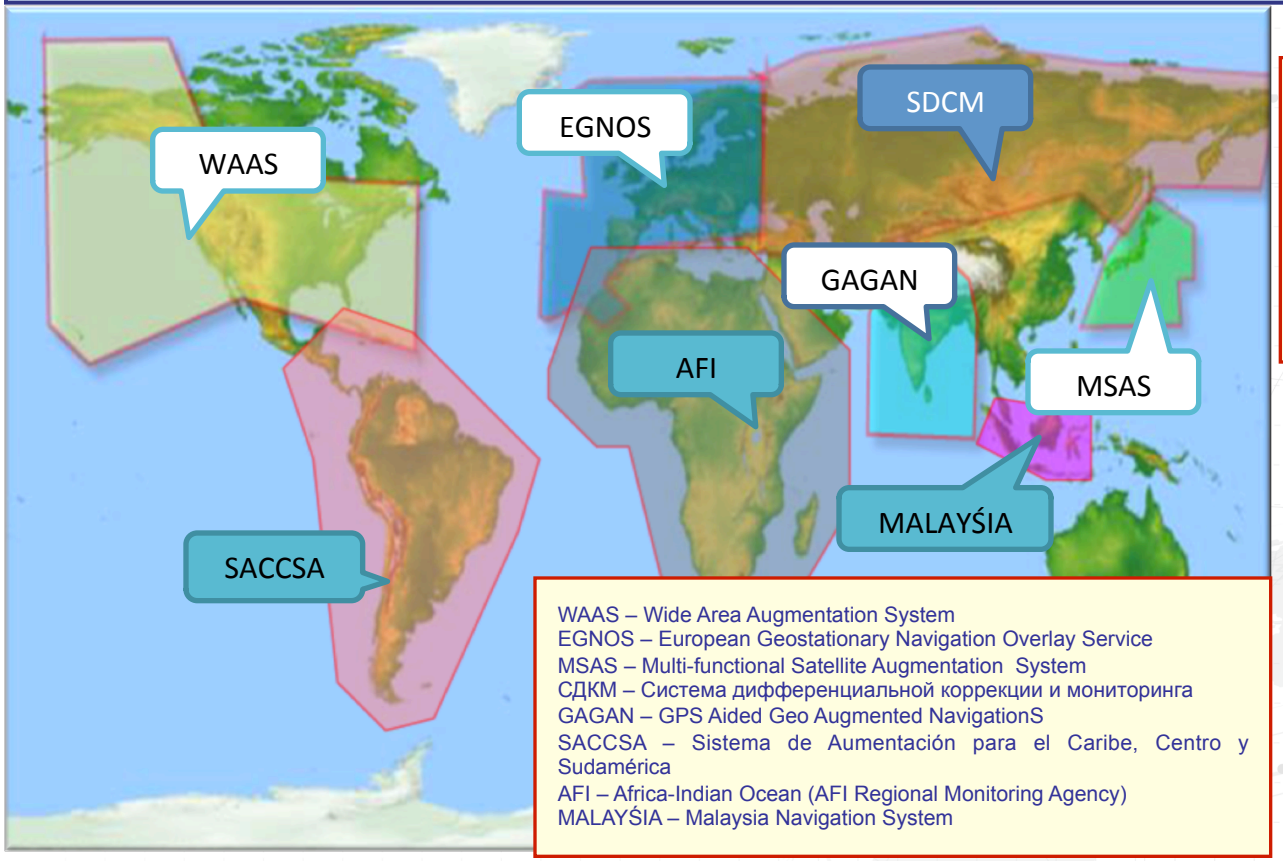
- Transportation
  - Navigation and traffic control
    - Aviation, marine shipping, railroad communications, highway transportation
- Power engineering, gas and oil shipment
  - Power lines synchronization, shipment synchronization
  - Power lines wiring and pipe laying
- Communications
  - Data transfer timing



Global navigation satellite systems augmentations

The Russian system for radio-navigation fields differential corrections and monitoring (SDCM) is a satellite navigation system augmentation for GLONASS and GPS that provides performance enhancement of the given systems for high accuracy solutions, updated and reliable integrity data.

SDCM developer – JSC «Russian Space Systems»



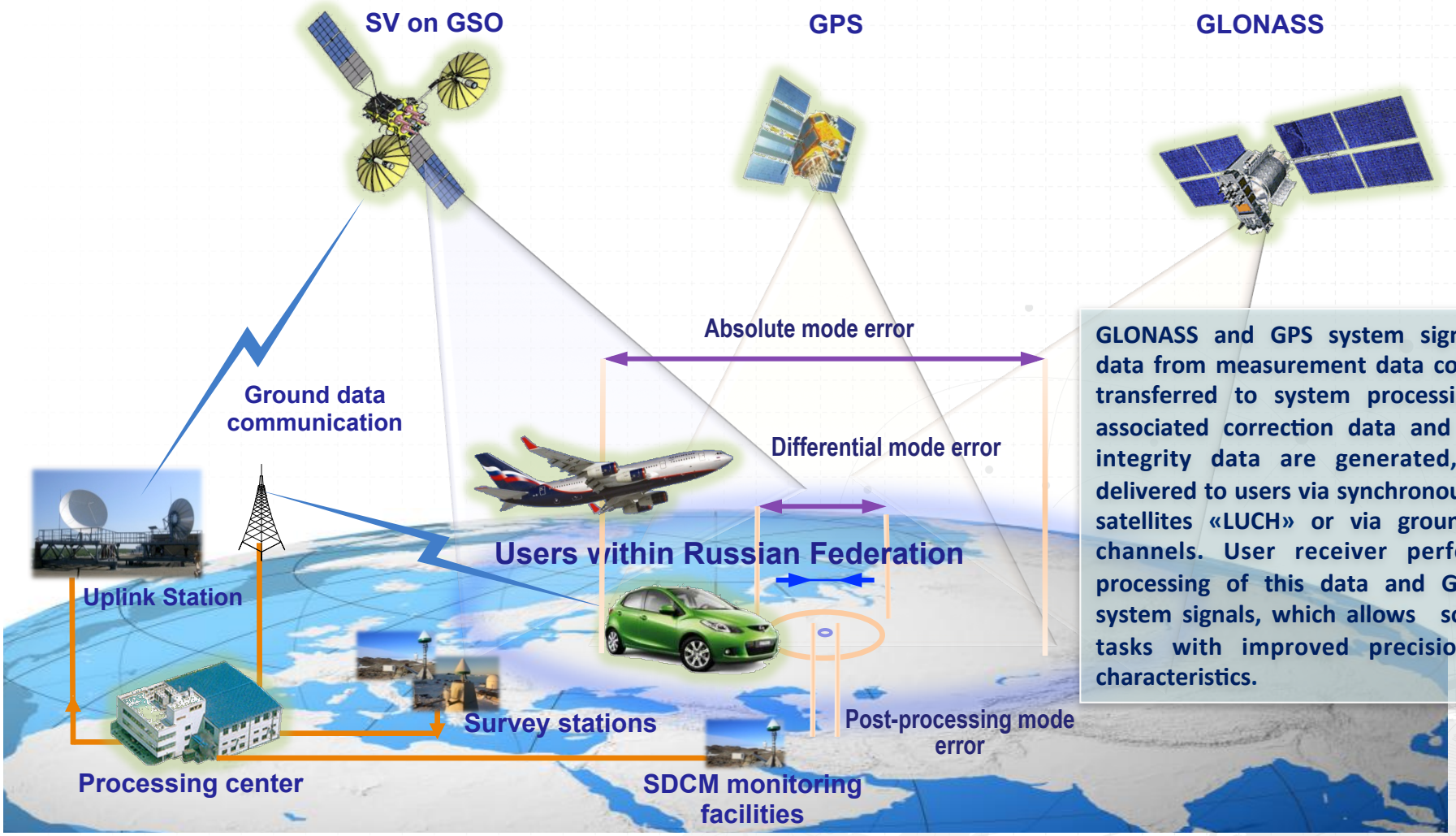
WAAS – Wide Area Augmentation System
EGNOS – European Geostationary Navigation Overlay Service
MSAS – Multi-functional Satellite Augmentation System
СДКМ – Система дифференциальной коррекции и мониторинга
GAGAN – GPS Aided Geo Augmented NavigationS
SACCSA – Sistema de Aumentación para el Caribe, Centro y Sudamérica
AFI – Africa-Indian Ocean (AFI Regional Monitoring Agency)
MALAYSIA – Malaysia Navigation System

Provides users with

- ephemeris data and time-and-frequency parameters corrections;
- vertical ionospheric delay factor;
- navigational field integrity data

—Current systems
—Deployed systems
—Future systems

SDCM – operating principles

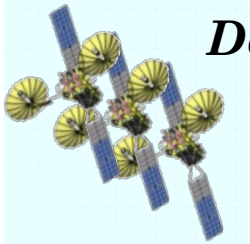


GLONASS and GPS system signals measurement data from measurement data collection stations is transferred to system processing center, where associated correction data and navigational field integrity data are generated, and which are delivered to users via synchronous communications satellites «LUCH» or via ground communication channels. User receiver performs overlapped processing of this data and GLONASS and GPS system signals, which allows solving navigational tasks with improved precision and reliability characteristics.

Russian system differential corrections and monitoring – new level of navigational support for GLONASS users

Current SDCM status

Data communication channels



✓ *3 SVs on GSO*

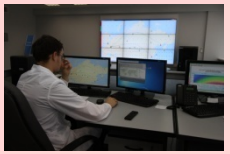
✓*SiSnet server*

Measurement data collection stations network

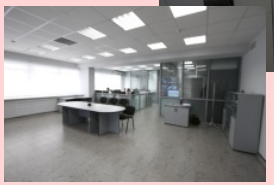
✓ *19 stations in Russia*

✓*4 stations abroad*

Processing center



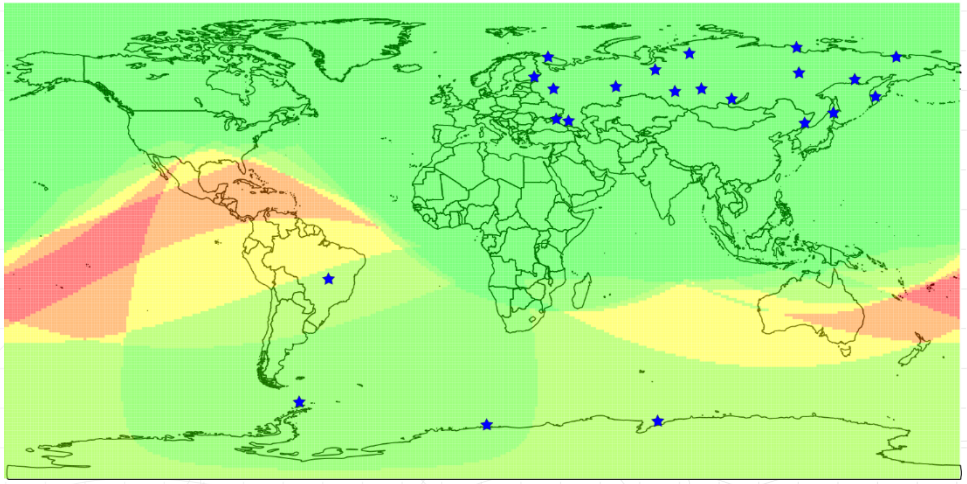
✓ *(Moscow)*



SDCM ground station network

19 reference stations within Russian Federation:
Leningrad Oblast (Pulkovo and Svetloye), Moscow (Mendeleyevo), Krasnodar Krai (Gelendzhik), Stavropol Krai (Kislovodsk), Novosibirsk, Irkutsk, Petropavlovsk-Kamchatsky, Sakha Republic (Tiksi), Vladivostok, Magadan, Yuzhno-Sakhalinsk, Murmansk Oblast (Lovozero), Yekaterinburg, Chukotka Autonomous Okrug (Bilibino), Tyumen Oblast (Noyabrsk), Sakha Republic (Yakutsk), Krasnoyarsk Krai (Norilsk)

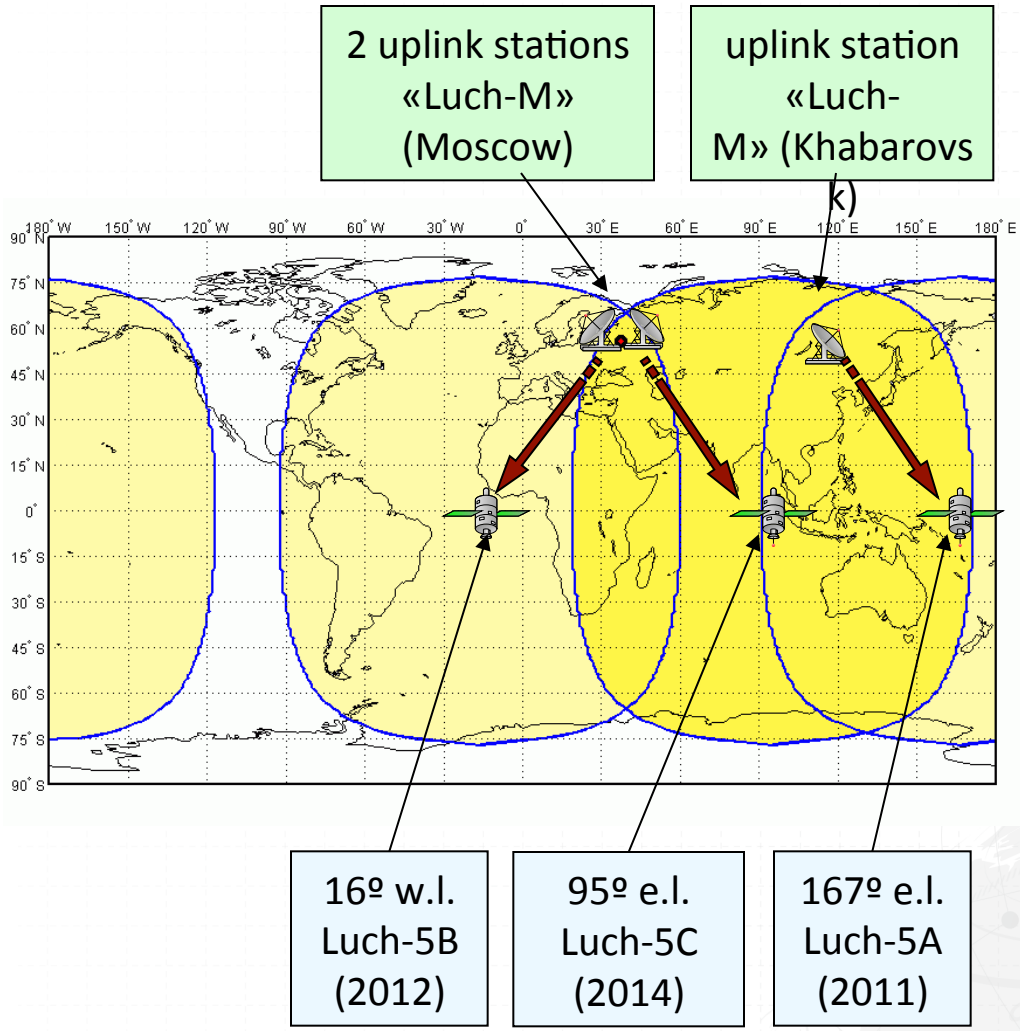
Stations abroad:
Antarctica (stations «Bellingshausen», «Novolazarevskaya», «Progress»), Brazil (Brasilia city)



Simultaneous SV observation from several stations

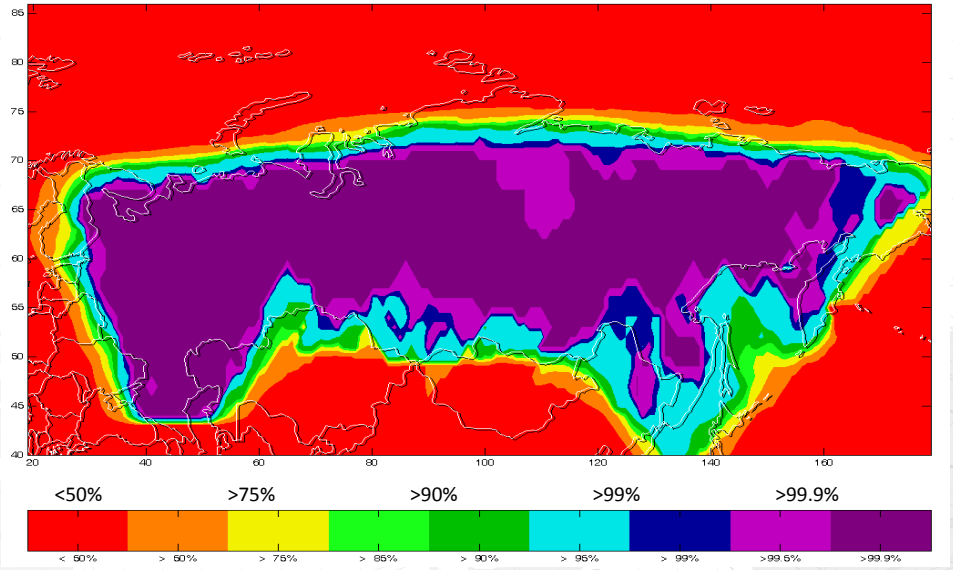
≥3 ст.	2 ст.	1 ст.	0 ст.

SDCM/user data communication complex

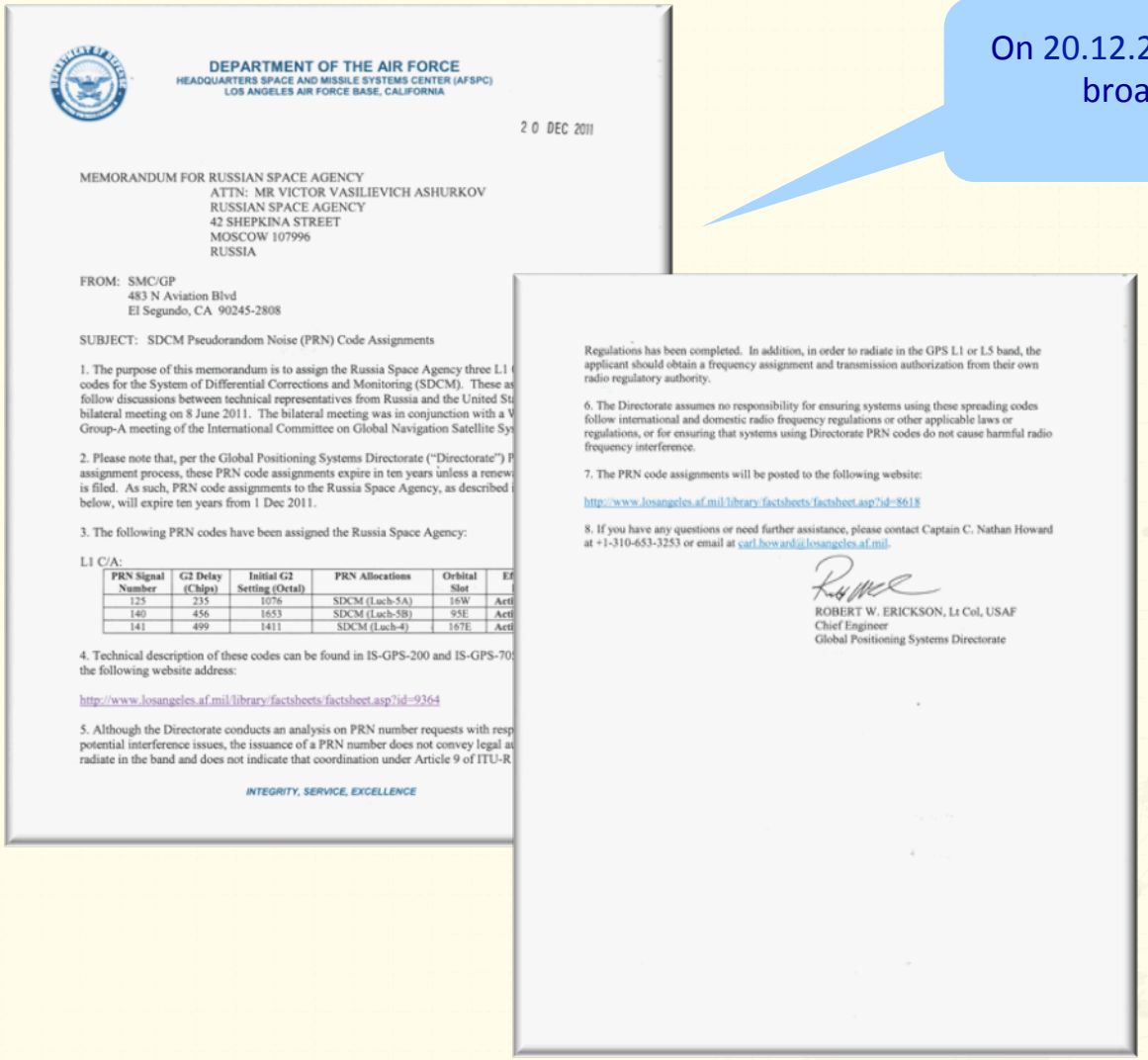


Based on SV «Luch-5A», SV «Luch-5B» and SV «Luch-5C» are deployed, and the development of SDCM-user data transfer via satellite channels is being performed. Data distribution is performed via L1-bandwidth signals (1575.42MHz) according to SARPs ICAO requirements and MOPS RTCA DO-229D.

SDCM accessibility within range coverage



SDCM is included in international GNSS augmentation system



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS SPACE AND MISSILE SYSTEMS CENTER (AFSPC)
LOS ANGELES AIR FORCE BASE, CALIFORNIA

20 DEC 2011

MEMORANDUM FOR RUSSIAN SPACE AGENCY
ATTN: MR VICTOR VASILIEVICH ASHURKOV
RUSSIAN SPACE AGENCY
42 SHEPKINA STREET
MOSCOW 107996
RUSSIA

FROM: SMC/GP
483 N Aviation Blvd
El Segundo, CA 90245-2808

SUBJECT: SDCM Pseudorandom Noise (PRN) Code Assignments

1. The purpose of this memorandum is to assign the Russia Space Agency three L1 (codes for the System of Differential Corrections and Monitoring (SDCM). These as follow discussions between technical representatives from Russia and the United St bilateral meeting on 8 June 2011. The bilateral meeting was in conjunction with a V Group-A meeting of the International Committee on Global Navigation Satellite Sy

2. Please note that, per the Global Positioning Systems Directorate ("Directorate") F assignment process, these PRN code assignments expire in ten years unless a renew is filed. As such, PRN code assignments to the Russia Space Agency, as described below, will expire ten years from 1 Dec 2011.

3. The following PRN codes have been assigned the Russia Space Agency:

L1 C/A:

PRN Signal Number	G2 Delay (Chips)	Initial G2 Setting (Octal)	PRN Allocations	Orbital Slot	Ef
125	235	1076	SDCM (Luch-5A)	16W	Acti
140	456	1653	SDCM (Luch-5B)	95E	Acti
141	499	1411	SDCM (Luch-4)	167E	Acti

4. Technical description of these codes can be found in IS-GPS-200 and IS-GPS-70 the following website address:

http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=9364

5. Although the Directorate conducts an analysis on PRN number requests with resp potential interference issues, the issuance of a PRN number does not convey legal a radiate in the band and does not indicate that coordination under Article 9 of ITU-R

INTEGRITY, SERVICE, EXCELLENCE

Regulations has been completed. In addition, in order to radiate in the GPS L1 or L5 band, the applicant should obtain a frequency assignment and transmission authorization from their own radio regulatory authority.

6. The Directorate assumes no responsibility for ensuring systems using these spreading codes follow international and domestic radio frequency regulations or other applicable laws or regulations, or for ensuring that systems using Directorate PRN codes do not cause harmful radio frequency interference.

7. The PRN code assignments will be posted to the following website:

http://www.losangeles.af.mil/library/factsheets/factsheet.asp?id=8618

8. If you have any questions or need further assistance, please contact Captain C. Nathan Howard at +1-310-653-3253 or email at carl.howard@losangeles.af.mil.

ROBERT W. ERICKSON, Lt Col, USAF
Chief Engineer
Global Positioning Systems Directorate

On 20.12.2011 PSP codes for differential corrections broadcast within L1 bandwidth (PRN 125, 140, 141) were acquired.

SDCM system provider ID is assigned in ICAO SARPs

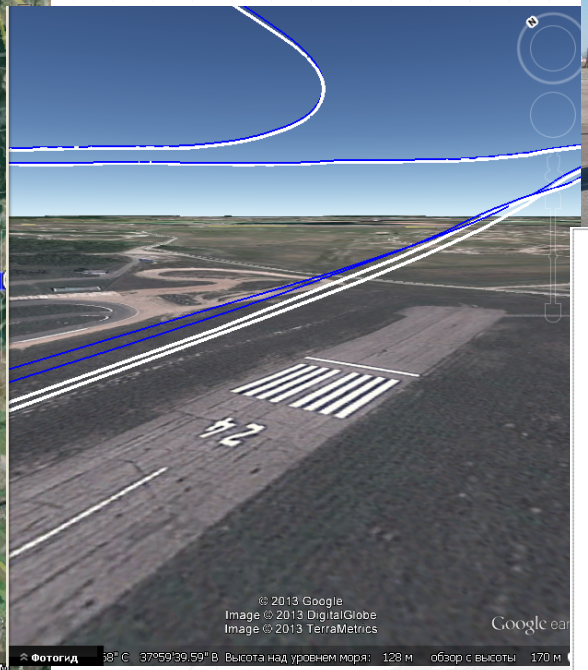
ДОБАВЛЕНИЕ В. ТЕХНИЧЕСКИЕ ТРЕБОВАНИЯ К ГЛОБАЛЬНОЙ НАВИГАЦИОННОЙ СПУТНИКОВОЙ СИСТЕМЕ (GNSS)

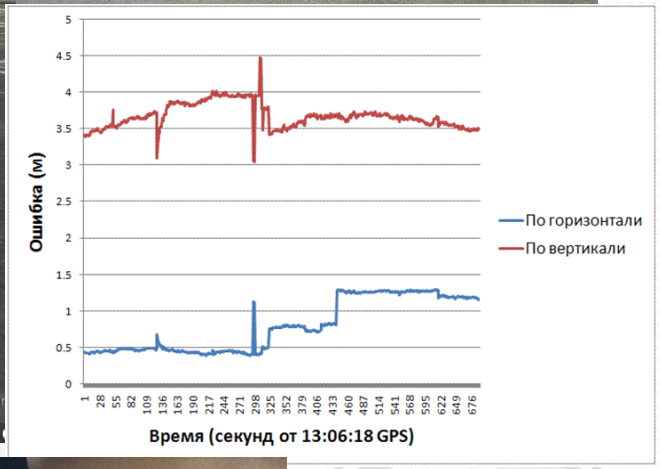
Таблица В-27. Идентификаторы поставщика обслуживания

Идентификатор	Поставщик обслуживания
0	WAAS
1	EGNOS
2	MSAS
3	GAGAN
4	СДКМ
5–13	Не занято
14, 15	Зарезервировано

Experimental performance verification (meeting the APV-2 requirements)

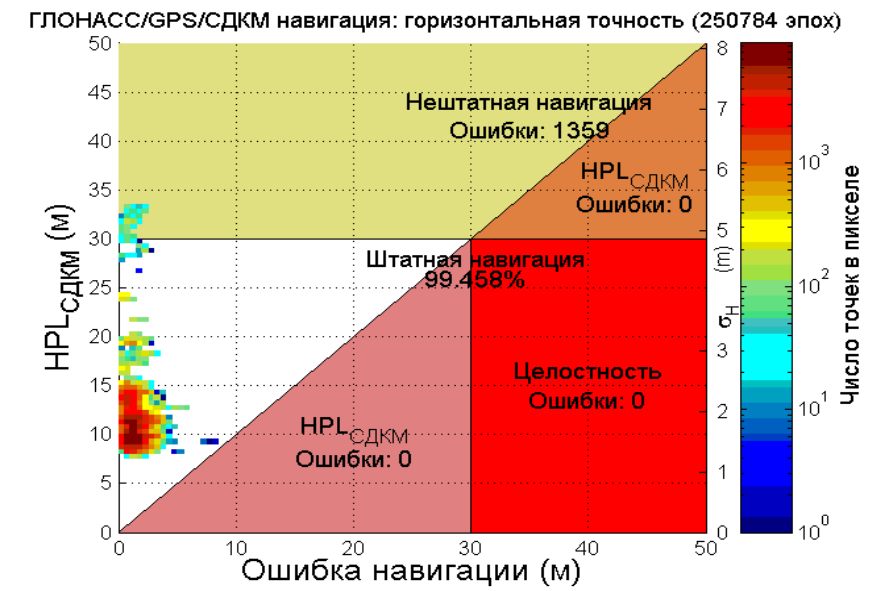
«Myachkovo» Airport

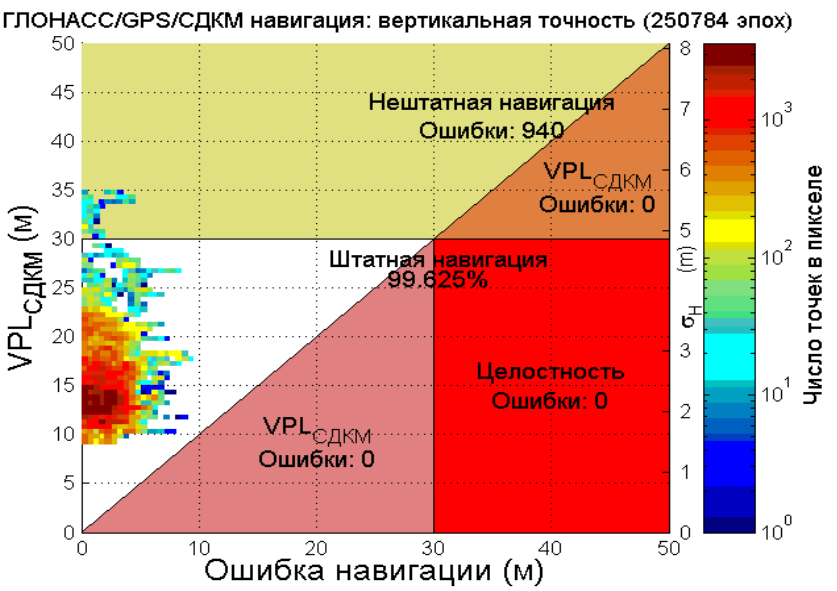


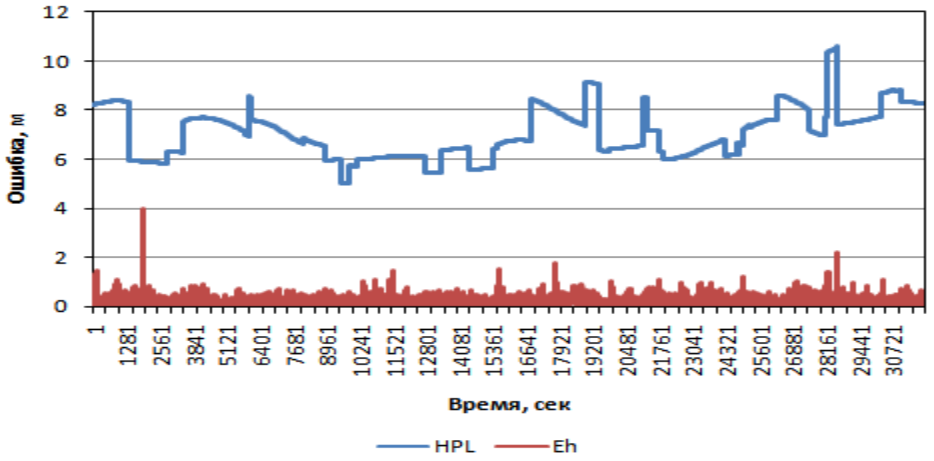


APV-2 requirements are met

Implementation of navigational sightings accuracy using SDCM experimental results







Potential SDCM applications

CIVIL AVIATION

- ❑ Landing approach according to ICAO categories
- ❑ Local flight

AGRICULTURAL INDUSTRY

- ❑ Motion control mechanization in small-seeded crop cultivation and yield mapping.
- ❑ Precise and effective field binding and automatic motion control during large-seeded crop cultivation.

ROAD FACILITIES

- ❑ Road processing monitoring to traffic lane
- ❑ Precise and effective construction sites binding within absolute coordinate systems

RIVER TRANSPORT

- ❑ Coastal ship navigation
- ❑ Precise and effective waterway signing and marking

RAILWAY TRANSPORT SECURITY

- ❑ Train position monitoring on adjacent railway lines.
- ❑ Shunting locomotive target optimization control

GEODESICS AND MAPPING

- ❑ Mapping database update.
- ❑ Pipelines and cable run mapping
- ❑ Natural resources mapping
- ❑ Real estate and construction area mapping

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Navigation accuracy consumer requirements

Occupation	Rms error, m
Road construction	0.03 - 0.05
Excavation and dredging	0.1 - 0.4
Railway status online monitoring	0.05
Railway construction and repair	0.03
Geodetic networks adjustment	0.03 - 0.05
Cadastral works, land survey	0.03
Mapping and planning updates	0.1 - 0.3
High-precision agriculture	0.1
Forest resources monitoring and management	0.1
Water resources monitoring	0.1
Mining operations	0.1

Precise point positioning technique development background

- Pseudo-phase measurements processing via GNSS signals allows navigational sighting implementation with a few cm precision
  - Classic approach is **RTK** (Real Time Kinematics)
  - In RTK mode, “specified” user coordinates are determined in relation to the nearest base station
  - Total measurement error of the base station and user is balanced out by generating second-order differences.
  - When using double-frequency measurements, ambiguity reveal is carried out almost instantly, which makes it perfect for precise positioning in real time

- However, RTK mode has a number of drawbacks:
  - RTK algorithm characteristics degrade with increasing distance from the base station, thus it’s necessary to set up a sufficiently dense base station network in a given region
  - Expensive base station network deployment and maintenance
  - Not always there is a possibility to set up a base station network with sufficient density

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Precise Point Positioning technique review

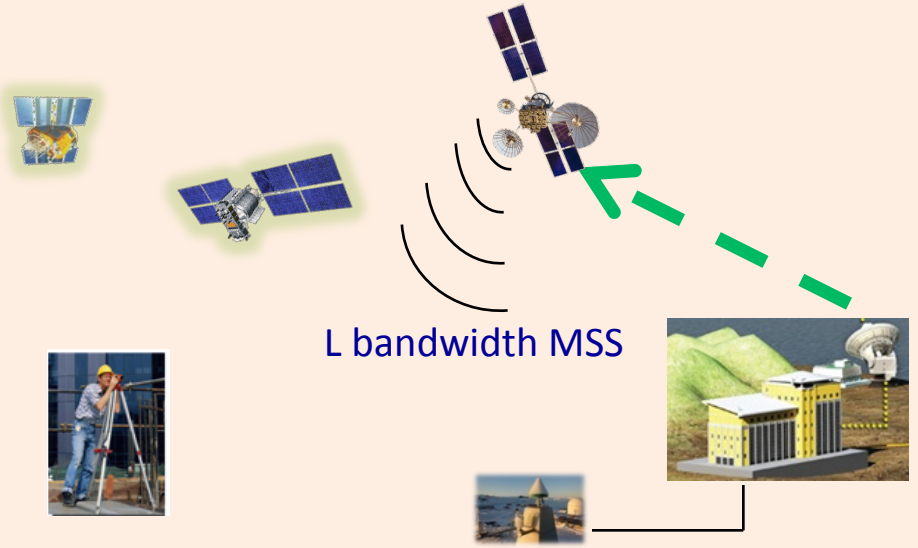
- Precise Point Positioning (PPP) is a global method, which doesn't require a designated base station network, but only needs primary measurements, generated by user navigation equipment
- In PPP mode preliminary calculated high-precision ephemeris and time-and-frequency parameters (TFP) are used
- Algorithm is based on using accurate models of all known effects (tropospheric refraction, Earth crust and ocean tides, antenna phase center shifts, phase spin, relativistic effects)
- Given that ephemeris, TFP and models are global, so precise point positioning is implementable everywhere in the world (on ground, in-flight and on the sea)!
- Precise point positioning is accomplishable via single- and double-frequency measurements in static mode or when moving
- Precise Point Positioning (PPP) provides high-precision absolute positioning with cm accuracy (same as RTK), also optionally provides:
  - ✓ User time scale determination and monitoring within 50 ps precision
  - ✓ Zenith tropospheric delay factor estimation within 5 mm precision

Wide-area and high precision navigation systems

Wide-area satellite-based augmentation systems (SBAS)

WAAS (USA), EGNOS (EU), MSAS (Japan), GAGAN (India)
Service for GPS users only
1 m accuracy (RMS)
Integrity 6 – 6.2 s
Service area: North America, Europe, Japan islands

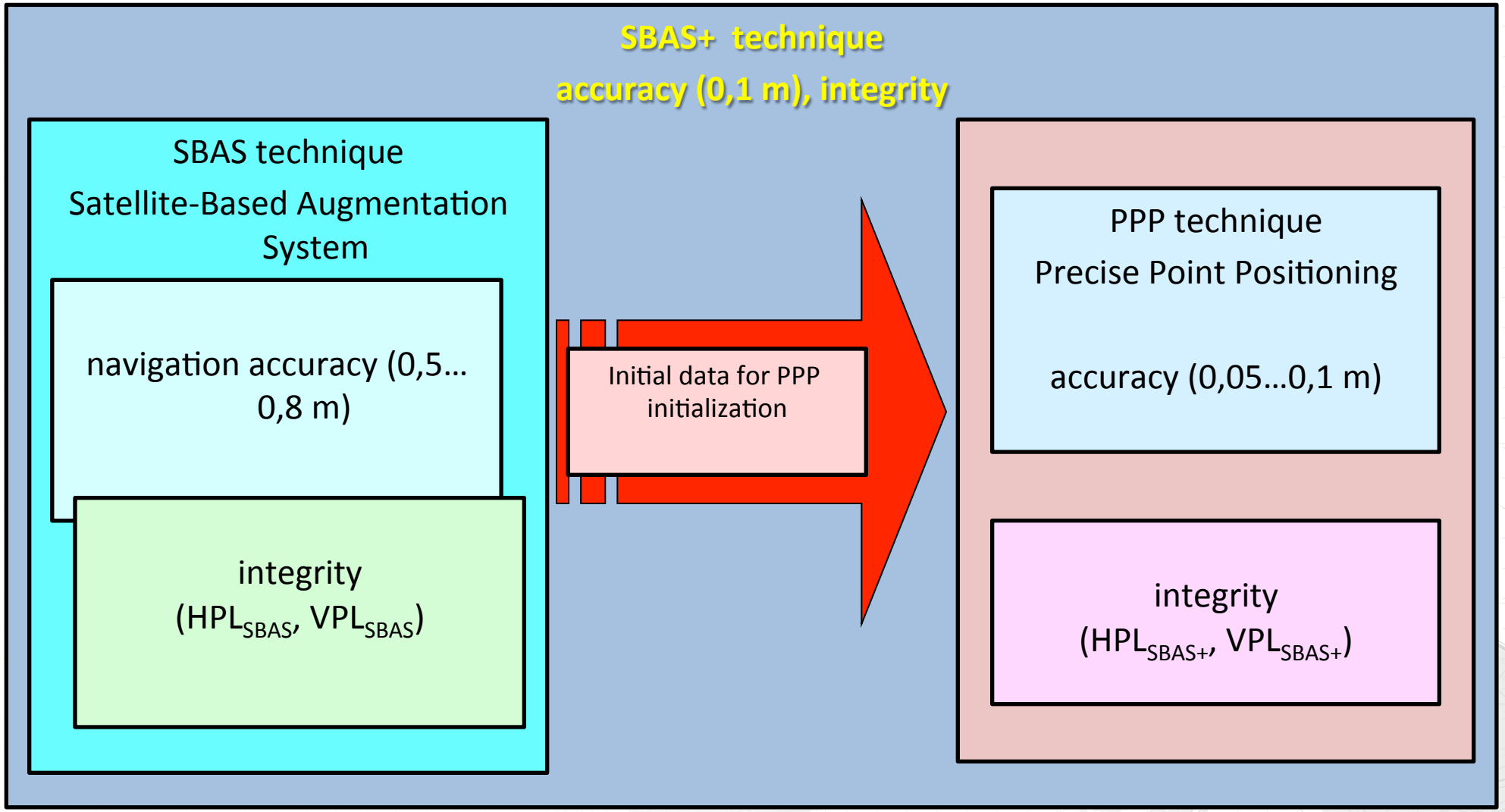
Commercial high precision navigation systems



OmniStar (USA), StarFire (USA)
Service for GPS and GLONASS users (OmniStar)
0.1 - 1 m accuracy (RMS)
Service area: global

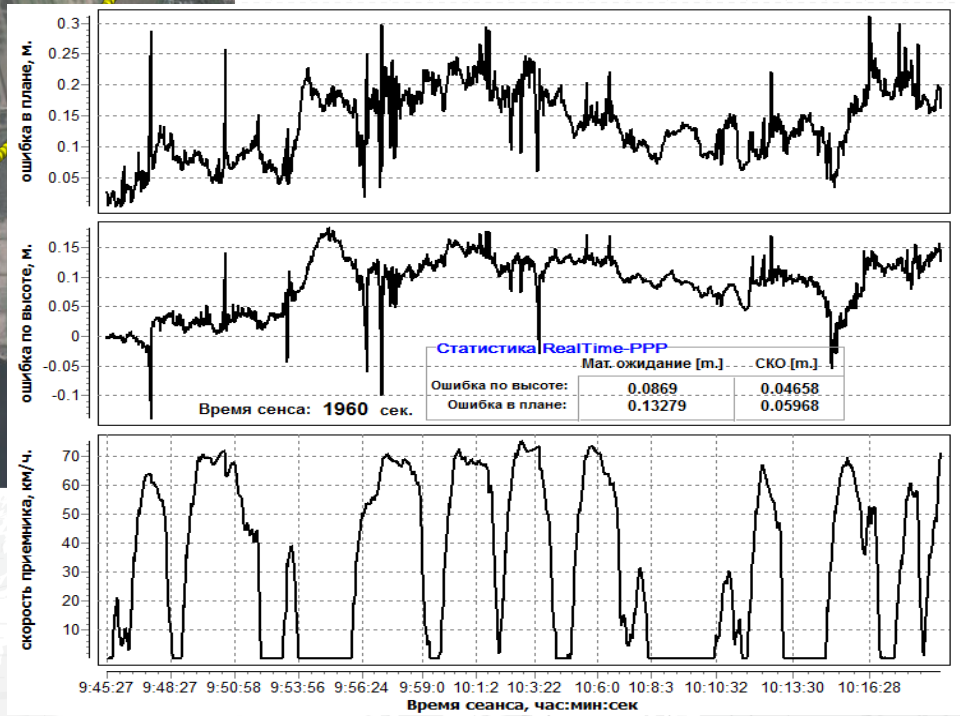
MSS – mobile satellite service

Wide-area GLONASS augmentation high precision complex: SBAS+ technique



SDCM development as a precise point positioning system foundation

Experimental use of the SDCM data in precise point positioning

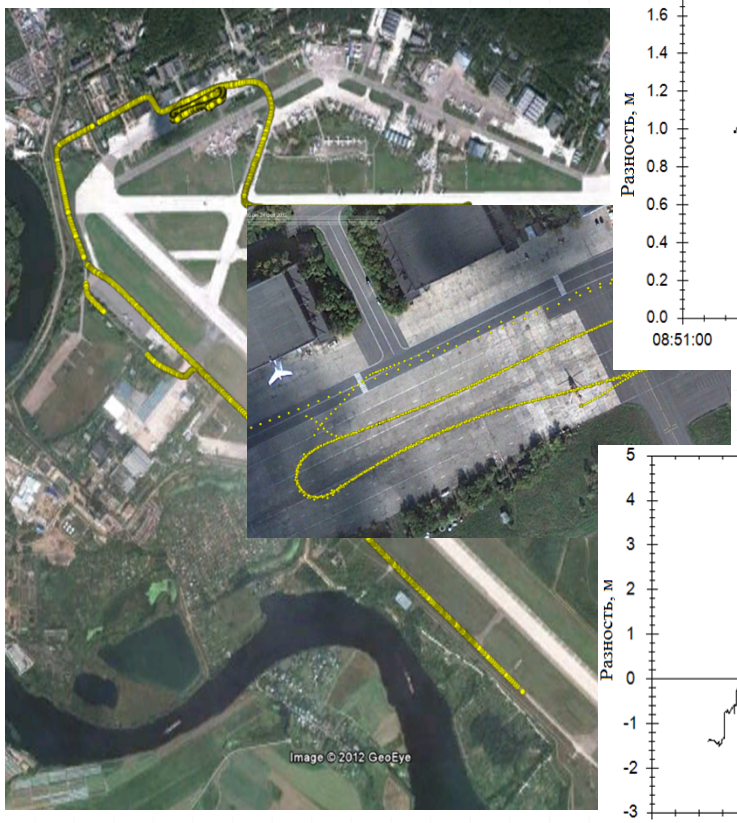


Mobile user positioning

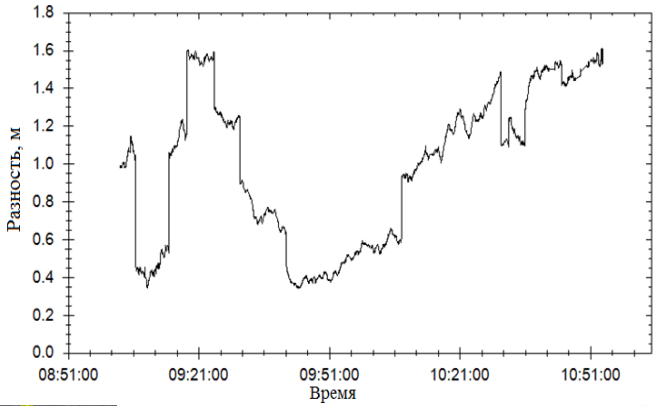
Absolute mode vs RTK

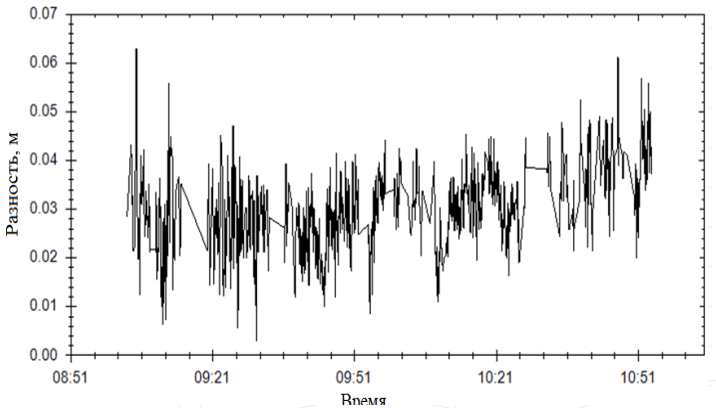
SDCM vs RTK

«Ramenskoye» airdrome

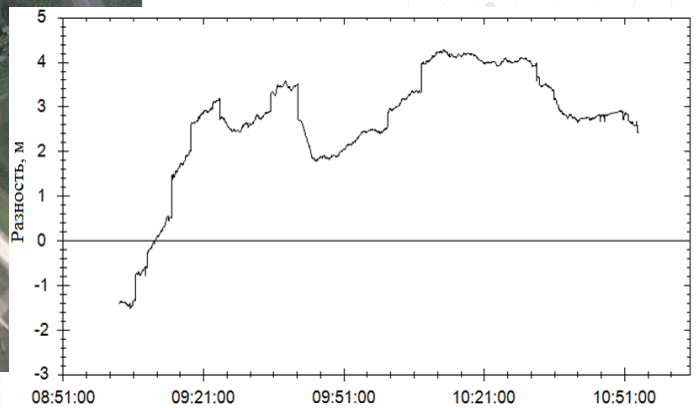


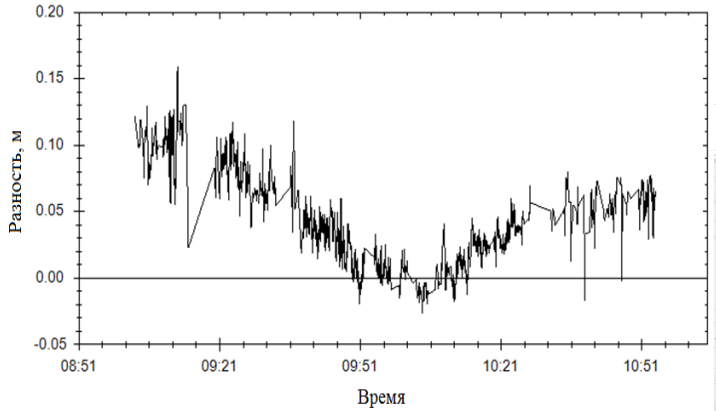
Plane coordinates





Altitude





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Conclusion

- ***Currently wide-area augmentation and monitoring system is developed, that provides differential corrections:***
  - ***In real time with 0.5 m precision (RMS)***
  - ***In post-processing mode with 0.05 m precision (RMS) within observation interval of 2 hours***

- ***High precision positioning techniques development allows to set up a global navigation satellite systems augmentation high precision complex based on SDCM***

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Thank you for your attention!

Vitaly Sernov
JSC Russian Space Systems
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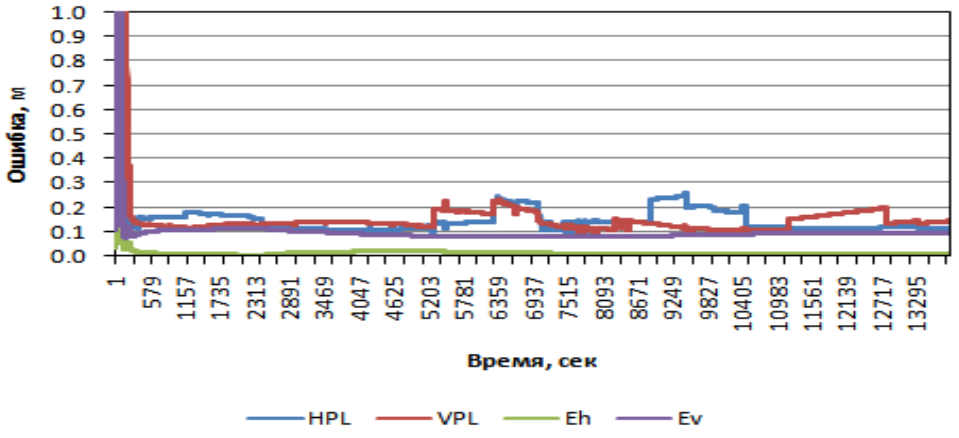
High precision navigation integrity experimental result

US GPS



US GLONASS/GPS