The Tenth Meeting of the International Committee on GNSS
1-6.11.2015, Boulder (USA)

Compatibility and interoperability of GNSS. Further discussions.

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Prospects of navigation satellite systems deployment

Global navigation satellite systems (GNSS)

- GLONASS (Russia) — 24 satellites (GNSS)
- GPS (the USA) — 30 satellites (GNSS)
- GALILEO (the EU) — 27 satellites (GNSS)
- BeiDou (China) — 27 satellites (GNSS)

Regional navigation satellite systems (RNSS)

- IRNSS (India) — 7 satellites (RNSS)
- QZSS (Japan) — 3 satellites (RNSS)
- BeiDou (China) — 10 satellites (RNSS)

Total: 4 GNSS and 3 RNSS

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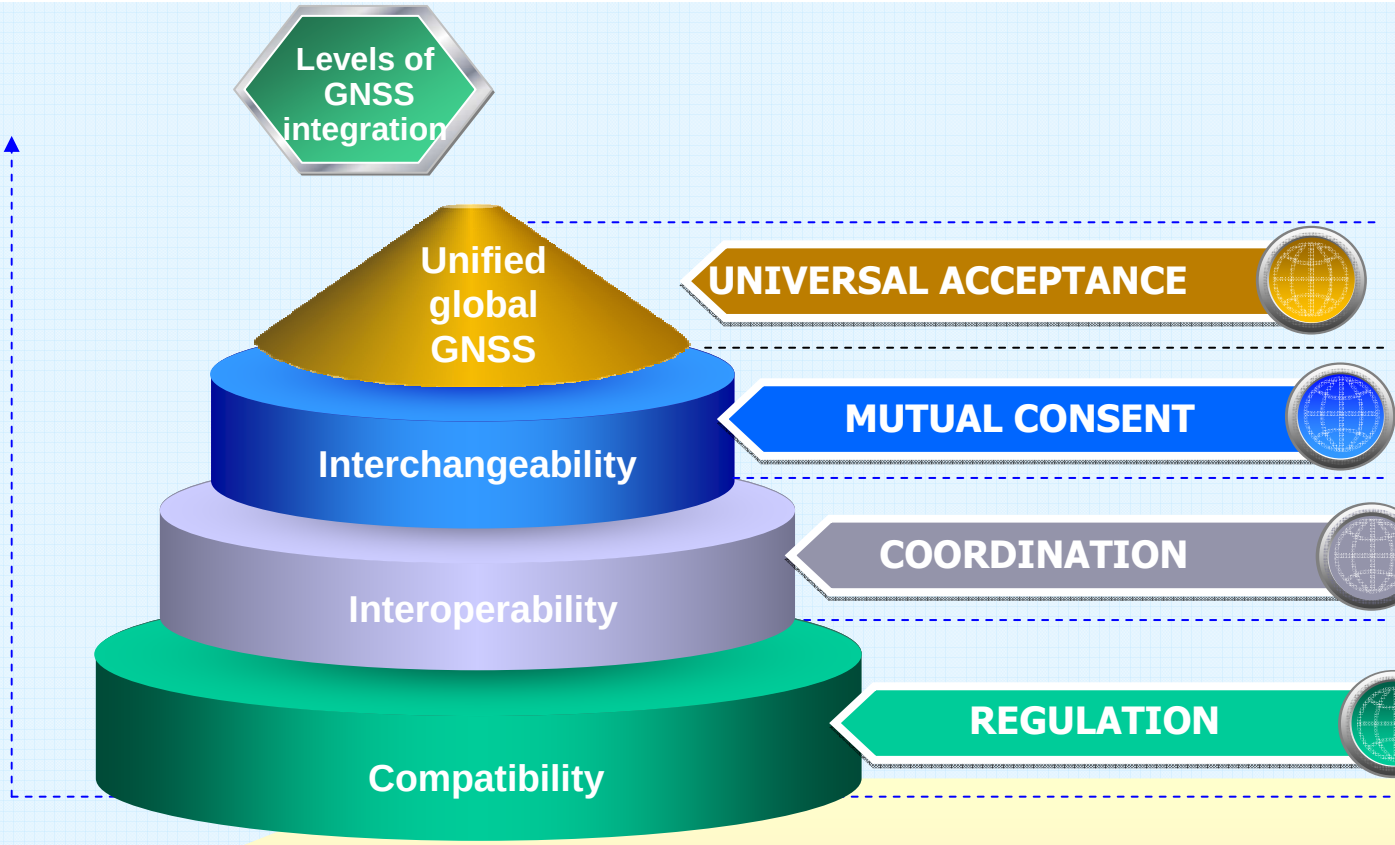
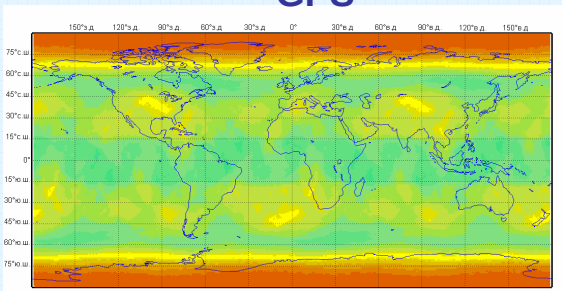
GNSS integration

ГЛОБАЛЬНАЯ НАВИГАЦИОННАЯ СПУТНИКОВАЯ СИСТЕМА ГЛОНАСС

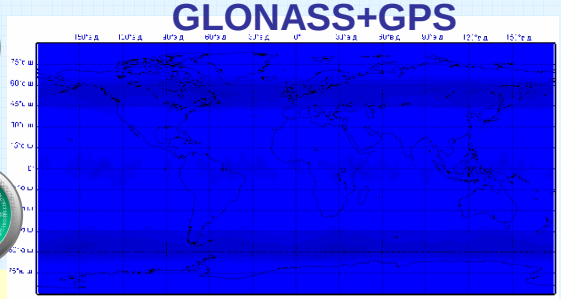


GPS

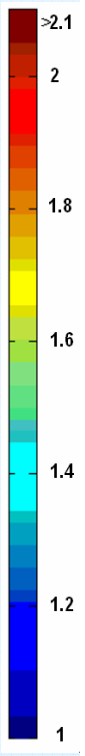


Average PDOP = 1,59 (P= 0,95)
Availability = 1,0

GLONASS+GPS



Average PDOP = 1,13 (P= 0,95)
Availability = 1,0



GNSS Integration (compatibility, interoperability, …) is one of the main purposes for international cooperation on satellite navigation.

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Compatibility of GNSS. Agreed definitions and statements.

Compatibility refers to the ability of global and regional navigation satellite systems and augmentations to be used separately or together without causing unacceptable interference and/or other harm to an individual system and/or service

***Fundamental principle:* not to interfere, not to harm.**

- The International Telecommunication Union (ITU) provides a framework for discussions on radiofrequency compatibility. Radiofrequency compatibility should involve thorough consideration of detailed technical factors, including effects on receiver noise floor and cross-correlation between interfering and desired signals
- Compatibility should also respect spectral separation between each system's authorized service signals and other systems' signals. Recognizing that some signal overlap may be unavoidable, discussions among providers concerned will establish the framework for determining a mutually acceptable solution
- Any additional solutions to improve compatibility should be encouraged

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Interoperability of GNSS. Agreed definitions and statements.

Interoperability refers to the ability of global and regional navigation satellite systems and augmentations and the services they provide to be used together to provide better capabilities at the user level than would be achieved by relying solely on the open signals of one system

Fundamental principle: it is better together than apart; together we are more efficient.

- Interoperability allows navigation with signals from different systems with minimal additional receiver cost or complexity
- Multiple constellations broadcasting interoperable open signals will result in improved observed geometry, increasing end-user accuracy everywhere and improving service availability in environments where satellite visibility is often obscured
- Geodetic reference frames realization and system time steerage standards should adhere to existing international standards to the maximum extent practical
- Any additional solutions to improve interoperability should be encouraged

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Significance of the ICG activity on GNSS compatibility and interoperability

Undoubtedly, development, discussion and implementation of GNSS compatibility and interoperability principles at the level of the ICG played and continue to play a positive constructive role in development, evolution and efficient use of navigation satellite systems.

It was held 9 ICG meetings and over 50 sessions and workshops of WGA on GNSS compatibility and interoperability.

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Further steps in evolution of GNSS compatibility and interoperability definitions

The following aspects are relevant for evolution of GNSS compatibility and interoperability definitions:

- Classification (structuring) of factors (characteristics of systems) which define (determine), respectively, level of compatibility and interoperability of GNSS;
- Development (coordination) of indicators and techniques of quantitative assessment of GNSS compatibility and interoperability level ;
- Elaboration of "GNSS interoperability" definition taking into account:
  - ✓ that there will be asymmetrical improvement in navigation quality when several GNSSs are used together if compared to the quality of navigation of each system used alone (issue of different accuracies of GNSSs);
  - ✓ existence, as a rule, of a fundamental (basic) GNSS and GNSSs which complement it;
  - ✓ before development of a multisystem receiver interoperability may be viewed as a potentiality.

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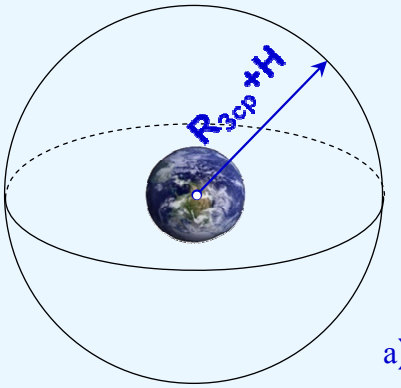
Orbital arrangement of GNSS as a factor of GNSS compatibility level

GNSS compatibility	**Radiofrequency compatibility** (spectral)	**Is regulated by ITU**
	Orbital compatibility	**?**

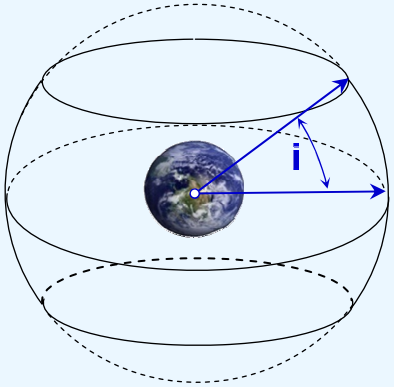
Orbital GNSS compatibility means a situation when there is no risk of unacceptable damage to GNSS due to a dangerous approach of operating GNSS spacecraft to each other and to space debris created during shaping and operation of orbital GNSS constellations.

GNSS space debris means defunct spacecraft and spent upper-stages (elements of upper-stages).

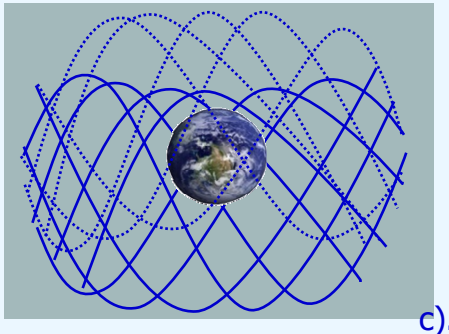
Orbital arrangement of GNSS



a).



b).



c).

$R_{Зср}$ – 6371,032 km; H – orbital altitude of GNSS spacecraft; i – orbital inclination of GNSS spacecraft.

GLONASS
i = 64,8 deg, H = 19 100 km

GPS
i = 55,0 deg, H = 20 190 km

BeiDou
i = 55,0 deg, H = 21 500 km

Galileo
i = 55,0 deg, H = 23 300 km

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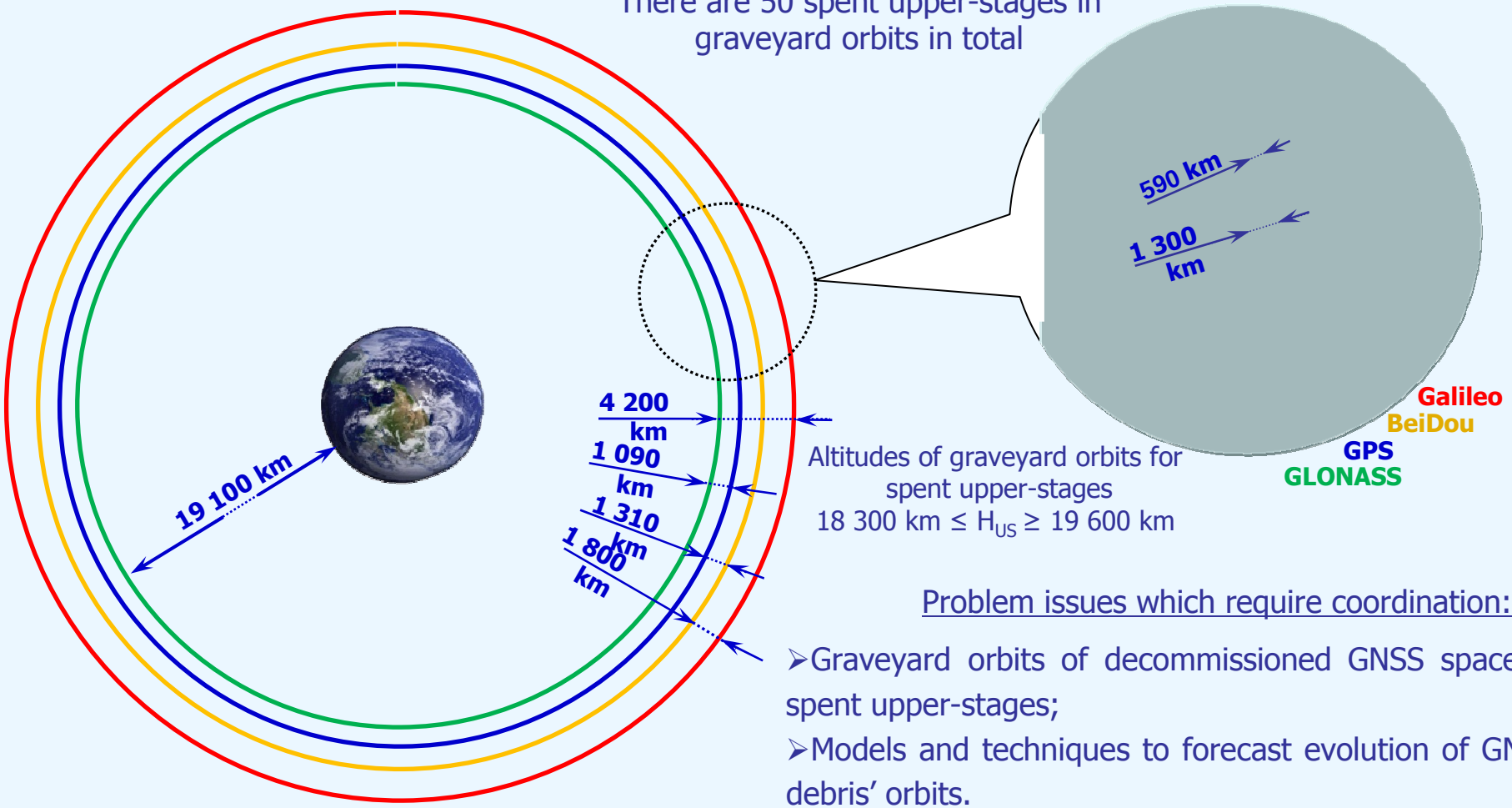
Graveyard orbits of GLONASS upper-stages

There are 50 spent upper-stages in graveyard orbits in total



Altitudes of graveyard orbits for spent upper-stages
18 300 km ≤ H_{US} ≥ 19 600 km

Problem issues which require coordination:

- Graveyard orbits of decommissioned GNSS spacecraft and spent upper-stages;
- Models and techniques to forecast evolution of GNSS space debris' orbits.

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Orbital arrangement of GNSS as a factor of GNSS interoperability level

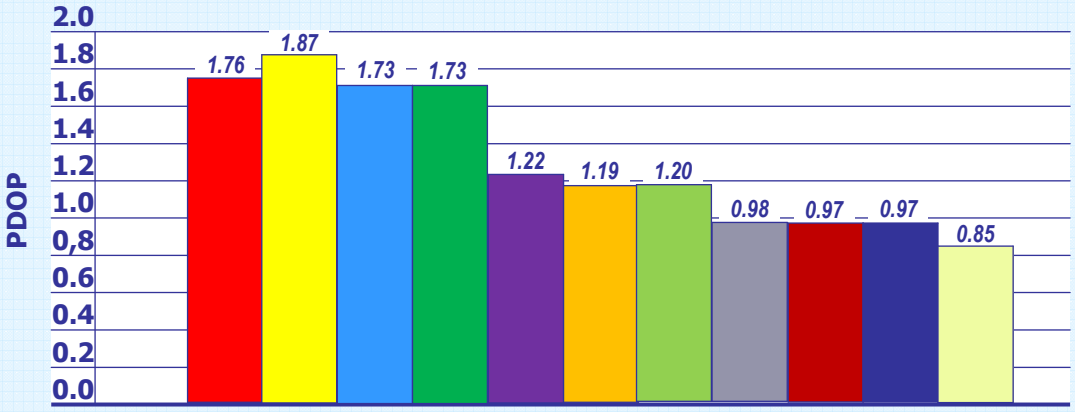
GNSS interoperability	**Orbital interoperability** (geometrical)
	Signal interoperability (spectral, informational,...)

Orbital interoperability of GNSS means ability to improve geometry of GNSS multiple combined constellations which broadcast open interoperable signals and as a result to increase accuracy of end user everywhere and to improve service availability in environments where satellite visibility is often obscured.

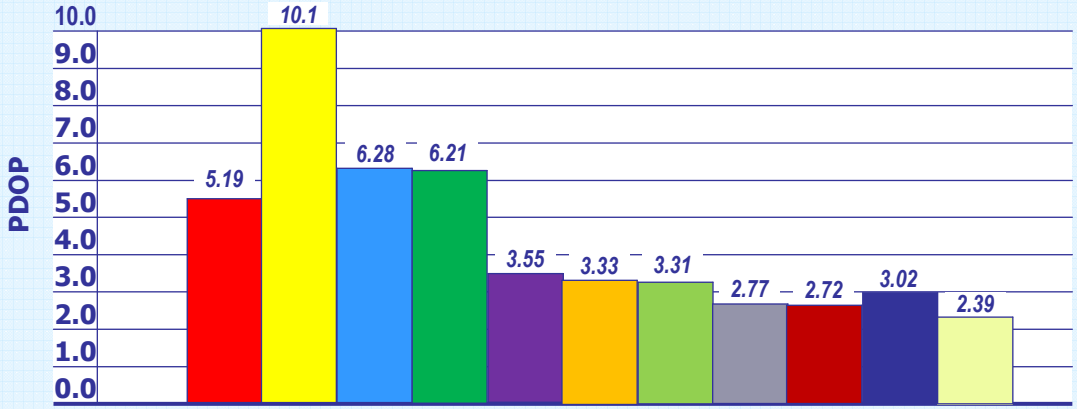
Quantitative assessment of geometry improvement can be made on the basis of changes in the value of "geometric factor" (PDOP), and quantitative assessment of availability – on the basis of changes in "availability" values.

Combined use of GLONASS, GPS, Galileo and BeiDou

Navigation in high latitudes (over 67°)
using GLONASS, GPS, Galileo и BeiDou, γ=5°



Navigation in high latitudes (over 67°)
using GLONASS, GPS, Galileo и BeiDou, γ=30°



- GLONASS
- GPS
- Galileo
-BeiDou
- GLONASS + GPS
- GLONASS + Galileo
- GLONASS + BeiDou
- GLONASS + GPS + Galileo
- GLONASS + GPS + BeiDou
- GLONASS + Galileo + BeiDou
- GLONASS + GPS + Galileo + BeiDou

Result of combined use of GNSS

GLONASS with GPS	Δ_{PDOP} = -1.84
GPS with GLONASS	Δ_{PDOP} = -6.55
Galileo with GLONASS	Δ_{PDOP} = -2.95

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Following steps

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Discussion of compatibility and interoperability principles should be continued at the level of the ICG Committee.

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Thank you for your attention!

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