

Fostering Science with GNSS

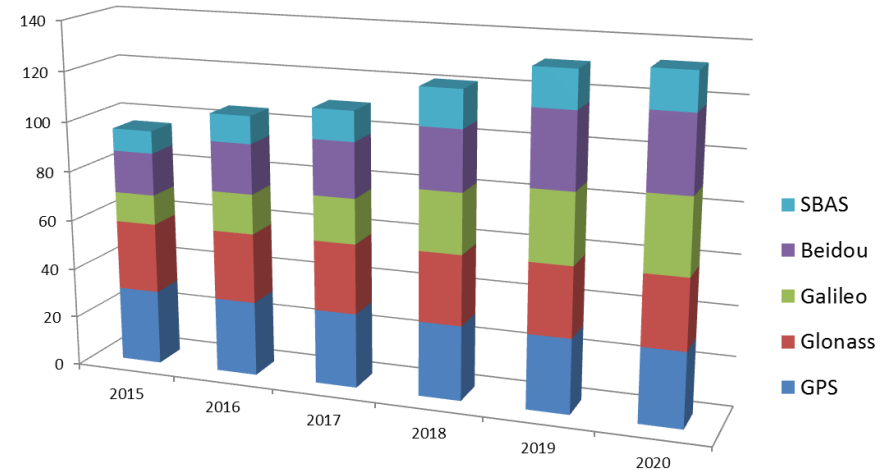
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ICG 11, Sochi, 7 November 2016

1. GNSS: Opportunities for Scientific Applications
2. ESA Activities Fostering GNSS Science
3. Examples of ESA Research & Development Activities
4. GNSS General Relativity Tests with Galileo
5. NAVIPEDIA – a tool for GNSS education
6. Conclusions

GNSS Infrastructure opens a unique opportunity for science:

- within this Decade more than 100 GNSS satellites become available
- multifold global coverage by high quality Signals in Space
- long-term measurements based on continuous GNSS data



Unique opportunity deserves promotion to ensure developments in a large variety of **scientific fields.**

Earth Science:

- Geodesy and Gravity Field Research
- Geodynamics & Seismology
- Earth Observation
- GNSS Reflectometry
- Atmospheric Research (Ionosphere & Troposphere)

Fundamental Physics:

- General Relativity
- Space-Time Symmetries
- Fundamental Constants
- Relativistic Reference Frames
- Quantum Mechanics

Space-Time Metrology:

- Time Scales and Offsets
- Contribution to Reference Frames
- Advanced Time Transfer Links
- Precise Orbit Determination
- GNSS synergy with VLBI and SLR

Other Fields:

- Astronomy and Astrophysics
- Solar-Earth Interaction, Space Weather
- Biomass Monitoring
- Tracking Wildlife / Migrations
- Robotic Exploration

1. GNSS Science Advisory Committee (GSAC)

Senior Advisory Body on scientific exploitation of navigation programmes

Interpreter of views/needs of European scientific community as regards uses of the GNSS programme for research in Earth, navigational and physical sciences.

2. ESA Galileo/GNSS Navigation Science Office

Overall coordination of ESA GNSS scientific activities. Responsible of activities to foster the consolidation of the European GNSS Scientific community.

3. Bi-annual Colloquium on Scientific and Fundamental Aspects of Galileo/GNSS since 2007

Bringing the European scientific community and their international partners together to reviewing and discussing the opportunities offered by GNSS signals to their research.

Next Colloquium scheduled for **25-27 October 2017** in Valencia, Spain

4. Research & Development Activities on GNSS Science

Announcement of Opportunities / Dedicated Studies by ESA

Purpose to **advise/ make recommendations** on:

- Needs of the scientific community & Scientific activities during the definition, implementation and exploitation of the European GNSS
- Medium and long term GNSS scientific policy in Europe
- Priorities of scientific community for future GNSS missions

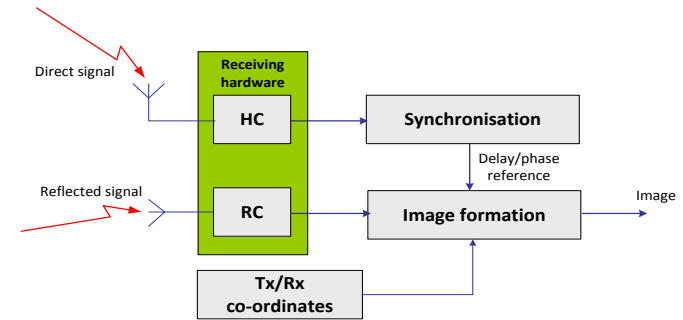
- Current Members:
- **Prof. G. Elgered (CHAIRMAN)** – Chalmers University of Technology, (SWE)
 - Prof. B. Dachwald – FH Aachen (DEU)
 - Dr. A. Bauch – Physikalisch-Technische Bundesanstalt (DEU)
 - Dr. P. Defraigne – Royal Observatory of Belgium (BEL)
 - Dr. P. Delva – SYRTE, Observatoire de Paris (FRA)
 - Prof. M. Hernandez-Pajares – UPC (ESP)
 - Prof. H. Kuusniemi – Finnish Geospatial Research Institute (FIN)
 - Prof. G. Lachapelle – University of Calgary (CAN)
 - Prof. T. Moore – University of Nottingham (GBR)
 - Prof. S. Oszczak – University of Warmia and Mazury (POL)
 - Prof. M. Rothacher – ETH Zurich (CHE)
 - Prof. F. Vejraska – Czech Technical University (CZE)
 - Dr. F. Vespe – Space Geodetic Centre, Matera (ITA)

Objectives of the Galileo/GNSS Navigation Science Office:

1. Provide **Scientific Support** to ESA on:
 - a. European GNSS infrastructure evolutions (EGNOS and Galileo) by recommending upgrades to enhance GNSS science opportunities.
 - b. Identification and development of complementary GNSS scientific infrastructure aiming at maximizing GNSS Science Opportunities in Europe.
2. Publication of **ESA GNSS Science Announcement of Opportunities**
3. Promote the cooperation among European States on GNSS Science.
4. Coordination and organization of the bi-annual ESA International Colloquium on Scientific and Fundamental Aspects of Galileo / GNSS and supporting other European specialized GNSS Scientific workshops.
5. Advise / provide support to **current and future ESA & European scientific missions and programmes** on the potential use of GNSS
6. Establish a **Reference GNSS Scientific data archive** integrating all available GNSS data sources

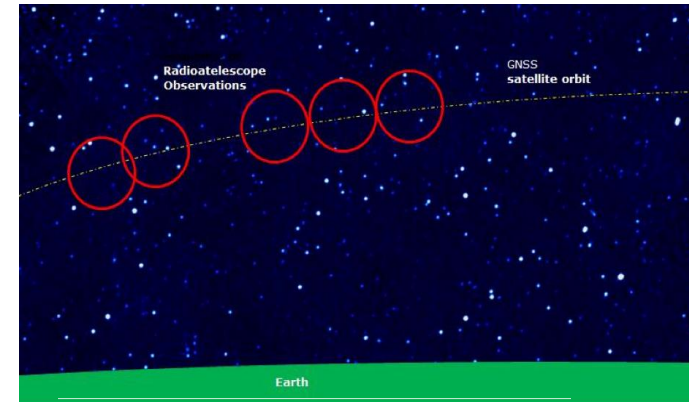
Galileo E5 AltBOC signal exploitation for Synthetic Aperture Radar imaging

utilize GNSS signals to passively produce high-resolution images of Earth.



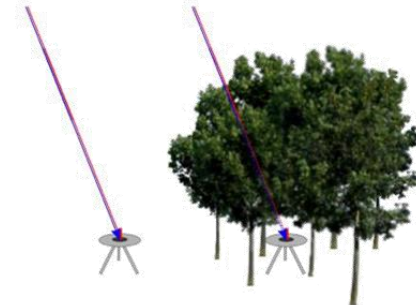
Real-time high accuracy measurements of ionospheric parameters

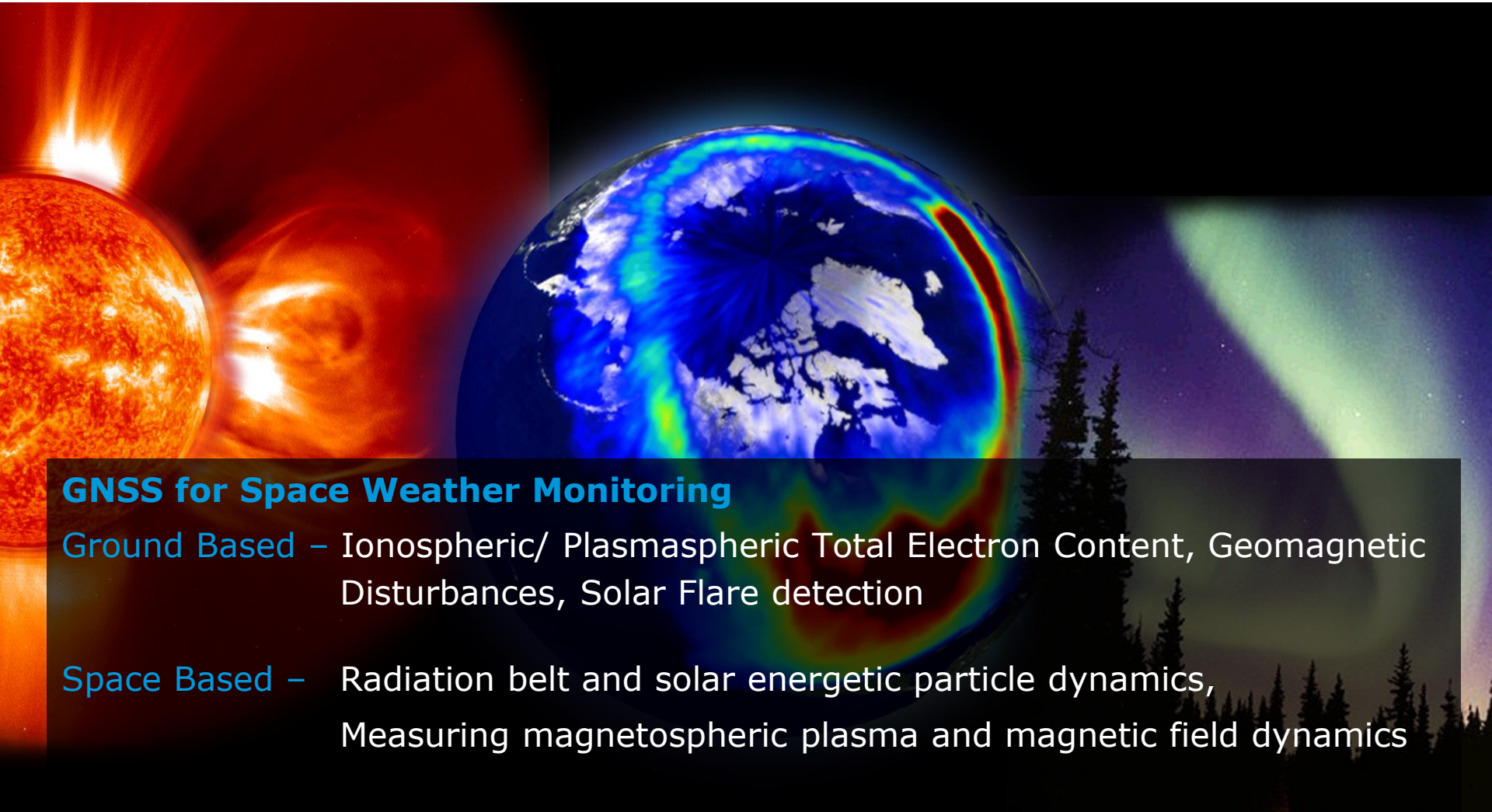
study added value of high accuracy ionosphere measurements by LOFAR radio astronomy telescope to GNSS; and the use GNSS-based ionospheric data for calibration of the LOFAR telescope.



GNSS for Biomass monitoring

study the use of GNSS for non-destructive *in situ* estimation of aboveground biomass (obtain insight on forests as carbon pools) and as means for ground calibration during ESA's Biomass mission.





GNSS for Space Weather Monitoring

Ground Based – Ionospheric/ Plasmaspheric Total Electron Content, Geomagnetic Disturbances, Solar Flare detection

Space Based – Radiation belt and solar energetic particle dynamics, Measuring magnetospheric plasma and magnetic field dynamics

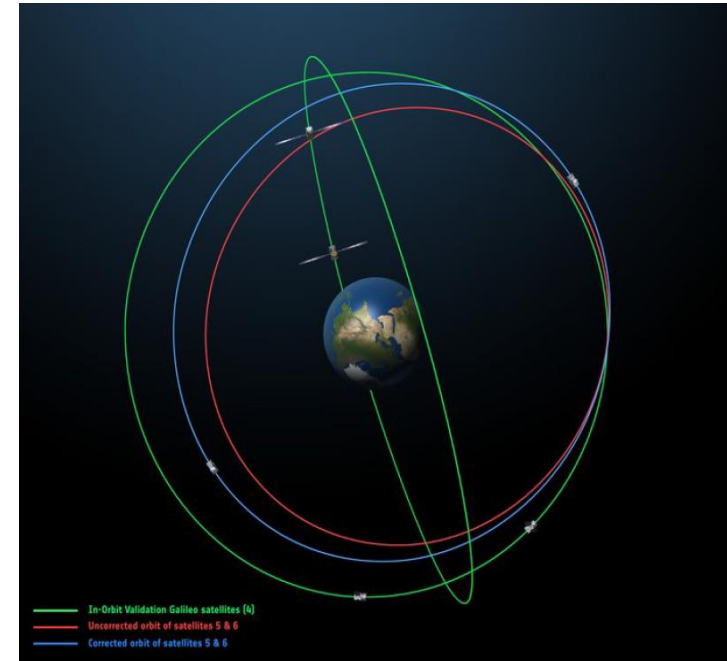
General Relativity Testing with Galileo Satellites GSAT0201/0202 (GREAT)

GSAT0201/0202 provide benefits to test Gravitational Redshift:

- Elliptic orbits → modulation of gravitational redshift
- Integrate measurements over long time periods
- High stability of PHM On-board clocks
- Satellites are monitored and include Laser retro reflectors for SLR tracking

Achievable accuracy of the gravitational redshift measurements could become “state of the art”.

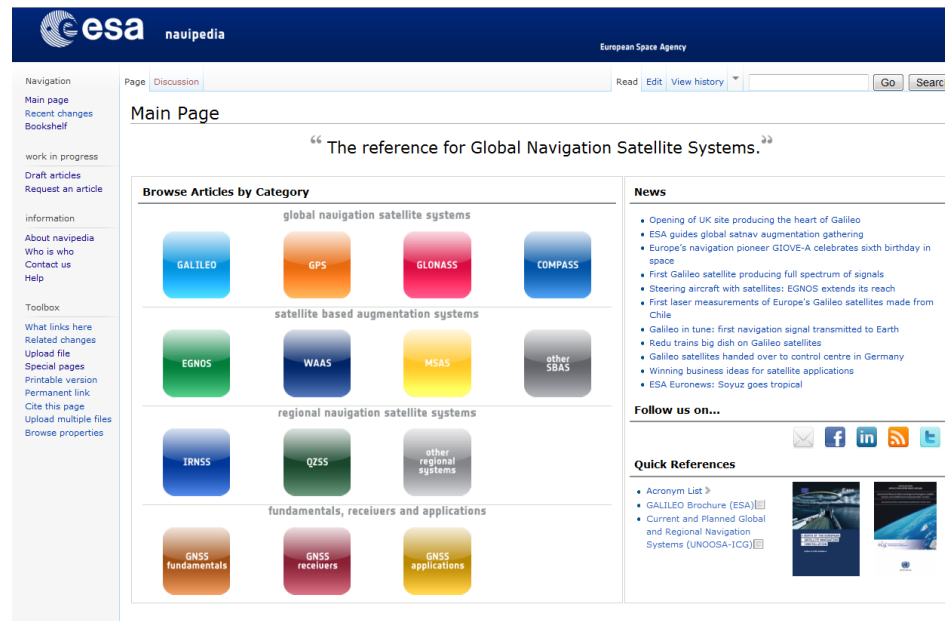
(today best measurements are still based on GP-A experiment performed in 1976)



Two contracts launched by ESA with SYRTE/Observatoire de Paris and ZARM/University of Bremen to perform these tests in detail.

Dedicated Presentation in WG-B

ESA has been **maintaining** and **developing NAVIPEDIA** with up-to-date information on the capabilities of the several GNSSs in line with ICG2012 recommendation



Complement of the provided information by Service Providers would be very useful to make NAVIPEDIA an excellent tool for GNSS education.

Dedicated Presentation in WG-C

Considering the build-up of the infrastructure **GNSS offer**:

- **Extraordinary potential** to support and advance in very wide range of **scientific applications**.
 - ICG could contribute to the identification of additional scientific opportunities by fostering cooperation between the GNSS systems and the Scientific Community.
- **Strong potential to improve Space Weather Monitoring** by coordination on space-based techniques
 - ICG could contribute to the identification of common methods for Space Weather monitoring from space.

NAVIPEDIA - solid and global reference for GNSS education.

Thank you!

Join us at the:

6th Colloquium on Scientific and Fundamental Aspects of Galileo/GNSS

25-27 October 2017 – Valencia, Spain



<http://esaconferencebureau.com/2017-events/17a08/introduction>