

gAGE/UPC

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The Research group of Astronomy and GEomatics (gAGE) belongs to the Technical University of Catalonia (UPC), in Barcelona, Spain. This is a public University under the jurisdiction of the Ministry of Science and Technology. Projects developed by the group are supported by public institutions and private industries, and they constitute the main founding source of the team.

The Research group of Astronomy and Geomatics (gAGE/UPC) is an interdepartmental group involving the Applied Mathematics IV and Applied Physics Departments of UPC.

gAGE/UPC Experience

The results achieved in the last years by gAGE/UPC have given to this university research group a high international acknowledgment, which has been shown in the adjudication of several competitive contracts from institutions and companies in the satellite navigation and aeronautical sectors (such as the European Space Agency [ESA], Eurocontrol, Galileo Joint Undertaking [GJU]...). Its members take part in several international groups of experts, have published more than 40 scientific papers in peer-reviewed journals and more than 150 papers in proceedings in the Global Navigation Satellite System (GNSS) field. In this context, several relevant contributions are detailed below:

1) gAGE/UPC has developed a new satellite navigation concept to make feasible the Centimetre-error-level navigation over Europe using, basically, the infrastructure of a network of stations already deployed by the European Space Agency for the EGNOS system (Augmentation System for Civil Aviation with a meter level of accuracy and a high integrity).

At present, such accuracy can be only achieved by means of a network of stations separated less than 20Km from the user (Real Time Kinematics [RTK]). With the new technique developed by gAGE/UPC (probably the first group in demonstrating the feasibility of the concept), the baselines between the reference stations can be extended up to hundreds of kilometres. Therefore, a precise navigation service for a whole continent becomes feasible with a very reduced infrastructure investment regarding to the present RTK system (only some tens of stations [as in EGNOS system] are needed, instead of thousands [as in RTK] for covering all Europe). On the other hand, the setting up of the system does not require a high investment, because it can use the network of reference stations already deployed for the EGNOS system, giving a double use to an investment already done. In 1999, gAGE/UPC patented the ionospheric part of the technique for GPS (Wide Area RTK [WARTK], gAGE/UPC patent) and, in 2002, the algorithms were extended to Galileo and modernized GPS and protected by several ESA funded patents (WARTK-3, in the context of a ESA project).

2) At present, gAGE/UPC is working very actively in the field of Precise Ionospheric Determinations. Since 1994 it is developing new algorithms for precise ionospheric and tropospheric sounding. In particular, a precise Ionospheric Model to reconstruct the tridimensional distribution of electrons in the ionosphere was developed, using measures of integrated electron density observed in different directions (tomographic model). In this approach (protected by a gAGE/UPC Patent N. 9902585), the GPS satellite constellation and the ground and Low Earth Orbiters LEO receivers are used as a huge planetary scanner for atmospheric sounding. This makes feasible to perform a real time reconstruction of its three-dimensional electronic distribution with different approaches (voxel models, improved Abel transform) and data sources.

Since 1998, gAGE/UPC is responsible of the generation and distribution of ionospheric correction maps for GPS navigation at a planetary scale, inside the International GNSS Service (IGS). This activity is done jointly with the three following centers: JPL/NASA, ESOC/ESA and CODE/Univ. Berna. Since 2002, M. Hernández-Pajares of gAGE/UPC is the chairman of this IGS ionospheric group.

3) Since 2001, gAGE/UPC is an active member of the EGNOS Data Collection and Analysis Working Group of Eurocontrol (the European organization for the safety of air navigation). This working group is devoted to the Operational Validation Activities for the EGNOS system, which is currently being implemented. gAGE/UPC has developed its own tools to analyze the SBAS (EGNOS/WAAS) signal, in both position and Signal in Space domains, including a Global Monitoring System (under a Eurocontrol contract) to analyze the performance of the EGNOS system over Europe on a daily basis.

gAGE/UPC, in collaboration with ESA, has developed several studies on the transfer of integrity from pseudo-range to position domains that have led to the Stanford-ESA Integrity Diagram (awarded by the US ION GNSS 2006). This technique is used to assess the robustness of the EGNOS system with respect to the integrity bound provision, for all possible satellite geometrical conditions. The Stanford-ESA Integrity Diagram has been adopted by the GNSS European Supervisory Authority (GSA) recommendations for the EGNOS safety certification as a tool for the integrity assessment in the position domain.

4) The Education activities of gAGE/UPC involve both, university and post-university levels. Since 1994, it creates and coordinates several lectures and Doctorate courses in GNSS data Processing and Applications at the Technical University of Catalonia (UPC). Also, it participates in several Master courses at the UPC and the Institute of Geomatics (Barcelona) since 1997.

In the international field, it participates in the Joint European-Asian education program on Galileo (ASIA@ITC from the European Commission) with several goals: to disseminate the knowledge of the new European Positioning System Galileo and its innovative features in Asian countries, to start up in Asia educational Laboratories and to create a group of experts with a common technical background. This project is coordinated by the Istituto Mario Boella ISMB from Torino, Italy, and incorporates the following partners: Politecnico di Torino (POLITO), Italy, the Technical University of Catalonia (UPC), Spain, the South East University of Nanjing (SEU), China, and the Hanoi University of Technology (HUT), Vietnam.

gAGE/UPC has edited a large amount of teaching material (presentations for courses and seminars, software, ...), including two GPS data Processing books, one of them both in Spanish and English.

5) gAGE/UPC created in 2009 the company **gAGE-NAV, S.L.** as a university *Spin-Off*.

Patents' details

- Wide Area Real-Time Kinematics with 3 frequencies (WARTK-3). Associated Patents: ESA Patent No. 02 12627, BR0317446 [Port.], 2849209(A1) [FR], 1576387(A2) [UK, North Ireland] 2004/057364 [UK, North Ireland], 1726406 [China], 7256730 [USA], 4230458 [JP], RU2318222C2 [Russian Federation], 235592 [India]. Inventors: M. Hernández-Pajares, J.M. Juan, J. Sanz (gAGE), A. García (ESA), 2002.
- Very Precise Ionospheric Corrections Determination for Satellite Electronic Navigation Procedure. Assoc. Patent: N.9902585: M.Hernandez-Pajares, J.M. Juan, J. Sanz (gAGE/UPC)
- Procedure of Autonomous Determination of GNSS Receiver Orientation with a single antenna, using its Ionospheric Information. Associated Patent N. P200402947. Inventors: M. Hernández-Pajares, J.M. Juan, J. Sanz (gAGE/UPC). 2004.
- Correction procedure of Travelling Ionospheric Disturbances in satellite based navigation and in GNSS receiver positioning. Associated Patent: N. P200602498. Inventors: M. Hernández-Pajares, J.M. Juan, J. Sanz (gAGE/UPC), 2006.

R+D+i projects

The activity portfolio of gAGE/UPC includes new algorithms for Wide Area navigation at the centimeter level of accuracy using GPS/Galileo, EGNOS performance assessment and precise Ionospheric and tropospheric sounding. As a University Research Group, part of its activity is also devoted to the Educational area, teaching in GNSS at different University levels (Lecturer, Masters & Doctorate). A selection of main recent projects is shown on the back page.



Project	Customer	Date	Key Features
SEAGAL	GSA	2009-2010	Implementation plan and set-up of a South-East Asia Centre on European GNSS for International cooperation and local development. Istituto Mario Boella (Coordinator), Politécnico de Torino, gAGE/UPC, Univ. Franche-Comté, Hanoi University of Tech., Asia Institute of Tech.
EPPP	ESA	2008-2009	Development of new algorithms for Real-Time Precise Point Positioning (accuracy and integrity). gAGE/UPC (coordinator), Imperial College of London, CTAE.
PRTODTS	ESA	2008-2009	Precise Real-Time GPS and Galileo Orbits and clocks determination. Responsible gAGE/UPC.
MRS	ESA	2007-2009	WARTK performance on accuracy and integrity is being studied in the Multi-Constellation GNSS Regional System (MRS). INDRA (coordinator), ASTRIUM, DEIMOS, gAGE/UPC, INECO, NovAtel.
AGIM	ESA	2008-2009	GNSS Contribution to Next Generation Global Ionospheric Monitoring. EDS (coordinator), gAGE/UPC, QinetiQ, DLR.
GNSS-Lab	ESA	2009	GNSS Educational tool. GNSS software package and tutorial with guided exercises. Responsible gAGE/UPC.
ION4	Starlab	2009	Mapping Function analysis and implementation from electron densities derived from GNSS Radio Occultations. Responsible gAGE/UPC.
EDCN	Eurocontrol	2008-2009	EGNOS Data Collection and Analysis Network. PILDO Labs (Coordinator), gAGE/UPC, TU-Delft, ENAC/SM3 Systems, IST Lisbon, Sofia TU and .BUTE.
FES-WARTK	ESA	2006-2009	Feasibility study for providing a future centimetre-error level GNSS navigation service based on EGNOS RIMS and Galileo systems, with special emphasis on both accuracy and integrity. gAGE/UPC (coordinator), TU-Delft and GMV.
GBAS-SPT	Indra	2008-2010	Support on GBAS activities. Responsible gAGE/UPC.
EGNOS-INTEGRITY	ESA	2006-2007	Support to ESA EGNOS Project Office on Continuity and Integrity Performance Assessment And Monitoring. Responsible gAGE/UPC.
WARTK-EGAL	GJU	2005-2006	The main goal of this project was to assess the potential of EGNOS RIMS network to support real-time subdecimetric navigation based on the Wide Area RTK technique developed by the gAGE/UPC authors of this proposal. It can suppose an enhancement of the service over Europe, from the meter-level accuracy of the incoming EGNOS system, to centimeter-level accuracy with WARTK. gAGE/UPC (coordinator), PILDO, FGI, ICC, IFEN.
JEAGAL	ASIA@ITC from the EU	2005-2007	Joint European- Asian Education Program on Galileo. ISMB –coordinator–, POLITO (Italy) gAGE/UPC (Spain), SEU (China), HUT, (Vietnam). The aim of the project was: to increase the knowledge of the new European Positioning System Galileo and of its innovative features in Asian countries, to start up in Asia educational laboratories on Galileo, to create a group of experts in the education on Navigation and Localisation.
EGNOS –Data Collection and Evaluation.	Eurocontrol	2006	From the methodology defined in the EGNOS SIS validation activities, the EGNOS system performance is analyzed against the system requirements. PILDO Labs (Coordinator), gAGE/UPC, TU-Delft, ENAC/SM3 Systems, IST Lisbon, Sofia TU and BUTE.
Analysis of EGNOS Ionospheric Corrections	ESA	2006	Analysis of the EGNOS ionospheric corrections and its integrity bounds during a strong ionospheric storm. Responsible gAGE/UPC.
Relativity and GPS	La Caixa	2005-2006	To design an experiment for the Science Museum exhibition of “Cosmo-Caixa Foundation” (Barcelona and Madrid exhibitions in Spain)
Neural Networks for Radio-Navigation.	ESA	2005-2006	Development of new algorithms based in Neural Networks to estimate and mitigate the multipath in the GPS navigation for Low Earth Orbiters (LEOs) satellites. M3Systems (coordinator), ENAC, gAGE/UPC, GMV.
EGNOS Ionospheric Studies	Eurocontrol	2005-2006	To develop different tests to analyze the EGNOS ionospheric corrections accuracy. They involve, in particular, the Long Baseline Ambiguity Fixing Techniques to compute very accurate ionospheric delays which are used as a reference for comparisons. Responsible gAGE/UPC.
Global Monitoring System for ESTB/EGNOS	Eurocontrol	2003-2004	A Global Monitoring System Tool (GMS) is developed by gAGE/UPC to provide a wide EGNOS performance monitoring over EUROPE on a daily basis, using the existing public domain data collection networks. gAGE/UPC and PILDO Labs.
ESTB/EGNOS Data Collection and Evaluation.	Eurocontrol	2002-2005	ESTB/EGNOS Data Collection working group project created by Eurocontrol In the frame of GOV (GNSS-1 Operational Validation). PILDO Labs (Coordinator), gAGE/UPC, TU-Delft, ENAC/SM3 Systems, IST Lisbon, Sofia TU and BUTE.
WARTK-3 Test Laboratory Campaign	ESA	2003-2004	Updating and WARTK-3 performance analysis using Galileo-like three frequency datasets generated by the ESTEC signal generator. Responsible gAGE/UPC.
WARTK-3 First study	ESA	2001-2002	Extension of WARTK algorithms to the three-frequency Galileo signals. Responsible gAGE/UPC.
SEARCH and RESCUE	Indra	2001-2002	Support in developing algorithms for Galileo Search and Rescue applications. Responsible gAGE/UPC.
Fulbright- 2000-002	Spanish-USA Fulbright . Coomiss.	2000-2002	Contribution of GPS ionospheric modelling to International Reference Ionosphere (IRI) updating gAGE/UPC-NASA.
MISSION PREDICTION for Navigation Applications.	Indra	1999-2003	Support in developing GPS and SBAS algorithms for navigation applications. Responsible gAGE/UPC.