Expression of interest, submitted in response to Call EOI.FP6.2002, for an Integrated Project[1]

SCIGAL: Earth Science Applications Using GALILEO

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1. Aim of the Proposed Work

The aim of the proposed Integrated Project is to mobilise the European scientific and technological expertise in Global Navigation Satellite Systems (GNSS) to develop the European know-how and offer a world leading expertise in high precision GNSS networks. This mobilisation will lead to the creation of an operational European GNSS tracking network, SCIGAL, that provides high-end users in Geodesy, Geophysics, Meteorology and Timing communities with relevant, up-to-date, scientific GNSS data services, products and tools. This proposal supports mainly the priority thematic area 1.1.4 ii (Space: GALILEO and GMES), but also the thematic area 1.1.6.3 (Global Change and ecosystems: operational forecasting and modelling, including global climate change observation systems).

SCIGAL contributes to the implementation of the European Strategy for Space through the development of an international science-driven infrastructure for GALILEO superior to the existing science-driven infrastructure for GPS. The research on GALILEO will focus on the development of tracking networks, receivers, tools and modelling for the scientific arena, but will also benefit to the high precision applications (e.g. surveying applications that require cm-accuracy) of general interest and support emerging GNSS networks run by meteorological institutes. In addition to the fundamental research that should make of GALILEO a high precision tool, a combined GALILEO&GPS based monitoring and tracking network will extend the knowledge of Earth science applications in the framework of GMES. These applications are: monitoring of European geodynamics, sea-level, climate change, space weather, meteorology, disaster management, precise positioning and precise timing. SCIGAL will set up a number of key services to facilitate these research areas and applications.

The integrated project contributes to the structuring and integration of European research by bringing researchers from various disciplines, government, industry and SME's together, through setting up multi-disciplinary services targeting the scientific, as well as, the applications of general interest. It aims to make Europe the world leader in GNSS research, in particular for the GALILEO system and avoids that the leading expertise is developed in the US or elsewhere only. It will stimulate European manufacturers of receivers to acquire a significant share in the high-end market of geodetic GNSS receivers.

The SCIGAL Integrated Project is related to the proposed Networks of Excellence EPISTAGE (IERS) and GARNET (University of Nottingham). With respect to these, SCIGAL is more directed towards developing concrete, user-oriented, as near real-time as possible, services based on (primarily) GALILEO, involving a strong industrial component and users group. EPISTAGE is more oriented towards the integration of different space geodetic techniques and improvement of the terrestrial reference system. GARNET on the other hand is more focussed on underpinning research and training.

2. Background to the Proposed Work

The International GPS Service (IGS) consists of a global GPS tracking network of over 300 receivers. It produces the most-precise satellite orbits and clocks, and contributes through its tracking station coordinates to the realization of the terrestrial reference system. The EUREF Permanent Network (EPN) is the European contribution to and densification of the IGS. The EPN consists of 130 permanent tracking stations distributed in more than 30 European countries. The EUREF sub-commission of the International Association of Geodesy manages the EPN and has created the structure for institutes to cooperate, share resources, develop and pursue standards, and make publicly available tracking and auxiliary data, as well as products of various kinds. The main achievement of EUREF is that it created, based on the EPN, a space geodetic reference system (ETRS89) that is used for georeferencing as well as for Earth science applications over the European territory. This reference system is supported by EuroGeographics; used by the industry; it is part of the legal framework of several EU countries and is recognized by the EU as the reference system to be used in Europe. Already now the EPN contributes to the monitoring of tectonic deformations in Europe and long-term climate monitoring. The European

[1] Although SCIGAL is proposed as Integrated Project, a Network of Excellence would be suitable as well.

COST action 716, in which several of the EPN stations and analysis centres participate together with meteorological institutes, has demonstrated that meteorological parameters can be computed in near real-time and can be used for Numerical Weather Prediction (NWP) and forecasting applications.

The combined use of GPS and GALILEO, as it is proposed in SCIGAL, will result in a significant improvement in the geodetic parameters, especially the height, troposphere delays, clocks and ionosphere parameters. It is the goal of SCIGAL is to start GALILEO observations on the EPN stations as soon as possible. This depends on two important conditions: firstly the development of high precision geodetic GALILEO&GPS receivers, and secondly the development of the necessary data-logging, data-communication, data-monitoring and data-analysis tools. The SCIGAL receiver should produce high accuracy code, phase and Doppler observations, on all accessible GALILEO and GPS frequency bands. To achieve precise atmospheric measurements and time transfer, special techniques should be developed for the automatic calibration of inter-system/frequency biases and overall equipment delays. Therefore, the development of high precision geodetic GALILEO&GPS receivers and antennae is a key element in this project. The development of innovative tools for data-monitoring, data-communication, data-analysis, etc., will enhance and stimulate the real-time operation, continuing growth and new applications of the network, provide station managers, data and analysis centres with a cost effective solution, and has a harmonising effect on the network procedures. The close interaction between the scientific community and the receiver manufacturers, as it is foreseen in SCIGAL, will ensure that, from the design stage on, both communities will maximally profit from each other’s expertise.

The SCIGAL network will provide collocations with time laboratories, tide gauges, radiosondes, water vapour radiometers, solar observation laboratories, seismometers and gravimeters. This will enable SCIGAL to improve the knowledge of European tectonics, ground deformations, sea-level change, ionosphere, and space weather. With the necessary research and development, GALILEO is expected to become a valuable tool for the calibration of ground and space based observations of water vapour in the new generation of meteorological satellites, and will be an important observable for climate research. In addition, the new signals that will be delivered by GALILEO will improve the precision of the time links realized by satellite geodesy. Using the collocation of some SCIGAL stations with time laboratories participating to the realization of the International Atomic Time, SCIGAL will be able to significantly improve the quality of time transfer and the generation, dissemination and synchronisation of very stable time scales. Therefore, SCIGAL is expected to contribute significantly to investigations in the field of reference systems, time keeping, meteorology, space weather and geodynamics.

Table 1 – Proposed SCIGAL results, products and services.

Level 0 - Station management, registration, data monitoring, web pages, guidelines	
L0a	Centralised web/ftp site with all info about SCIGAL operation (fully dynamic)
L0b	Registration service for new GALILEO+GPS tracking stations and maintenance of meta information
L0c	Instructions and downloadable software for setting up new tracking stations
Level 1 - GPS+GALILEO tracking data (code & phase)	
L1a	Real-time data service for the real-time subnet (internet based)
L1b	Full data dissemination and archiving service through operational data centres (in a standard format to be developed)
Level 2 - Analysis centre products (scientific and professional products)	
L2a	Set of reference stations with coordinates known in a homogenous European and global reference system usable for all geo-referencing in Europe in the EU reference (ETRS89)
L2b	Real-time satellite orbits and clocks, ionosphere models and troposphere delays
L2c	Post-processed satellite orbits and clocks, ionosphere models and troposphere delays
Level 3 - End user products	
L3a	Differential correction data for the RT network stations
L3b	Network RTK (Real-Time Kinematic) and Virtual Reference Station data
L3c	Zenith Total Delays and Integrated Water Vapour for NWP, weather prediction, climate
L3d	Ionosphere products for space weather
L3e	Time transfer
L3f	Velocity fields

SCIGAL will include a substantial real time and near real time component. This is important to facilitate precise carrier phase navigation and positioning, improve the prediction of precipitation in Numerical Weather Prediction and weather forecasting. This service will focus on accurate real time and near real time products for scientific, environmental and professional users. The products will be disseminated through the Internet. For instance, meteorological institutes plan to assimilate zenith delays from dense GNSS networks into their NWP-models for weather forecasting typically relying on SCIGAL for fast orbit and clock products in near real time. Another example is precise carrier phase positioning, which would rely in addition on a real time ionosphere product, to provide their users with decimetre to centimetre accuracies. SCIGAL products for precise carrier phase positioning and navigation may be distributed using wireless techniques (e.g. UMTS), as in a few years these will reach into almost every corner in Europe with a wide data rate bandwidth.

3. Need & Relevance of the Proposed Work

The close cooperation between scientific institutes and industry will ensure that the use of signal in space and user equipment meets the highest possible scientific standards and requirements, which cannot be obtained by either group alone. This is necessary to make Europe the world leader in GNSS research, in particular for the GALILEO system and avoids that the leading expertise is developed in the US or elsewhere only. It is therefore essential that the proposed work will be completed before the GALILEO system becomes operational in 2008. Furthermore, this will stimulate European receiver manufacturers to acquire a significant share in the high-end market of geodetic receivers, and will help and stimulate European industry in the development of new applications.

A combined GALILEO&GPS based high precision monitoring and tracking network will stimulate and extend the knowledge of Earth science applications in the framework of GMES such as: monitoring of European geodynamics, sea-level, space weather, meteorology, precise positioning and precise timing by setting up a number of key services to facilitate these research area's and applications. Starting from the existing collocations in the science-driven EPN, SCIGAL will make systematic observations of atmospheric and terrestrial parameters necessary for global change research, including climate change.

The key service offered by SCIGAL will also benefit European surveyors and real-time high precision navigation applications. With research and development, SCIGAL will become a valuable tool for the calibration of ground and space based observations of water vapour in the new generation of meteorological satellites, and is an important observable for climate research. Once operational, it will continuously test and calibrate the GALILEO technology.

4. Activities to Achieve the Proposed Objectives

One of the main goals of SCIGAL is to give industry and the scientific community a flying start into the operational GALILEO system in 2008. In order to achieve this goal, the three phases of activity described in Table 2 are foreseen.

Table 2 - Proposed activities for SCIGAL

Phase 1: GALILEO/GPS receiver equipment for scientific applications (2003-2006)	
P1a	Definition of requirements for scientific high-precision GALILEO/GPS receivers
P1b	GALILEO/GPS receiver studies, design and development (high accuracy code, phase and Doppler observations on all the GALILEO and GPS frequency bands, multipath suppression techniques, special tracking techniques for static receivers, calibration for precise time transfer, calibration of inter-frequency biases for atmospheric sounding, antenna calibration)
P1c	Development for data monitoring tools, data formats, receiver interface for remote control, software for (near) real-time data communication and data archiving (seamless data archive)
P1d	Study and implementation of GALILEO observations into scientific processing software
P1e	Earliest possible deployment and testing of GALILEO/GPS prototype receivers at a few selected sites
Phase 2: GALILEO/GPS prototype network (2004-2008)	
P2a	Deployment of GALILEO/GPS receivers at selected IGS/EPN sites (global & European coverage)
P2b	Set-up of AC's and experimental product generation (post-processing) (for products see separate list)
P2c	Development of tools for the real time-subnetwork
P2d	Evaluation of hardware and software, receiver testing
P2e	Finalization of standards, formats, etc.
Phase 3: Start of full deployment (2008-)	

A key element to the project is the development of high quality GALILEO&GPS receivers and the tools to operate them by the industrial partners, in close cooperation with the scientific community. At the same time, the scientific community will prepare the full integration of GALILEO and GPS through the elaboration of the appropriate modelling and algorithms. After this first step, the existing European GPS network, EPN, will be upgraded with GPS&GALILEO receivers, existing services will be enhanced and new real-time scientific and high-precision services will be developed. At that time, industrial partners can manage the distribution of the services. In this way, the receivers take advantage of a huge test-bed. Phase 3 actually coincides with the end of the project. We will use the EPN model to continue operations, but with much improved products and tools.

Different types of networks are foreseen: a real-time core network for the computation of real-time orbits and satellite clocks in close cooperation with IGS and a real-time ionosphere product; a near real-time network forming the bulk of the SCIGAL network; and a post-processed network with a few additional stations in inaccessible places that are of importance for Earth science applications. One of the objectives of this project is to develop the (software) instruments to manage such a large network at all levels. E.g. station managers should have software to collect the data and to let them monitor the performance of their station (using the data from the network). The tools that will be developed should be open (available to all). Also, a clear classification of the stations (geophysical, meteorological, etc.) will be needed. The amount of monitoring and attention depends on the type of station.

5. Proposed Consortium

The proposed consortium (see table 3) consists of academic institutions, government agencies, industry and SME's, covering a wide range of expertise, working towards a common goal, each from its own background. SME's play an important role in the project. Several of the SME's are involved in the design of the SCIGAL GALILEO receiver, data tools and communication aspects, whereas others are working on new applications, such as Network RTK and Virtual Reference Stations.

Table 3 - Provisional SCIGAL consortium.

Academic/Institutional	Country	Chief Scientist	Area of Excellence	Role in project
Institute of Geodesy and Geophysics, TU Vienna	A	Robert Weber	A2 A5 A6 U2	L2bc L3a P1d P2b
Space Research Institute, AAS	A	Peter Pesec	A2 A3 A4 A6 A7 U3 C1	L0c L1a-b L2a L3bc
Royal Observatory of Belgium [3)]	B	Carine Bruyninx	A2 A4 A7 U2 U4 C1	L0a-c L2a L3de P1e P2ab
Astronomical Institute, University of Berne	CH	Urs Hugentobler	A2 A5 A6 A7 U3 U4	L2ac L3ef P1d P2b
SwissTopo	CH	Elmar Brockmann	A2 A3 A6 U1 U2 U3 N1	L2a L3a-c P1e P2a-c
Research Institute of Geodesy, Prague	CZ	Jan Kostelecky	A2 A4 A5 A6 U3	L1b L3bcf P1e P2a
Bundesamt fur Kartographie und Geodasie [3)]	D	Georg Weber	A2 A3 A4 A6 T1	L1a L2ac L3ac P1c P2a-c
Universitat Politecnica de Catalunya, Astronomy and Geomatics [3)] (gage/UPC)	E	Manuel Hernandez-Pajares	A1 A2 A3 A7 A8 U2	L1a L2bc L3abd P1bc P2c
CNRS Laboratoire de Géologie	F	Christophe Vigny	R2 N1	P1a
Institut Géographic National	F	Zuheir Altamimi	A1 U3	L2a
Institut de Physique du Globe de Paris [3)]	F	Philippe Lognonne	A7 A8 U1 U3	L3d
Finnish Geodetic Institute	FI	Marku Poutanen	U3	L3cf P1ade P2ade
FOMI Satellite Geodetic Observatory	H	Ambrus Kenyeres	A2 U3 T3 N1	L2a L3f P2abde
Italian Space Agency (ASI) [3)]	I	Francesco Vespe	A2 A3 A4 A5 A6 U1 U3	P1d P2bc
University of Padova	I	Alessandro Caporali	A2 U2 U3	L1a L2a L3abf P1d P2ab
University of Latvia, State Land Service	LV	Kazimirs Lapuska	A2 A4 A5	L1b L2a L3e P1e
Norwegian Mapping Authority	N	Hans-Peter Plag	A2 A3 A5 U2 U3	L1a L2a P1e P2ac
Delft University of Technology, MGP [3)]	NL	Hans van der Marel	R2 A1 A2 A4 A6 U1 U2 U3	L1a L2a-c L3bc P1a-e P2a-e
Delft Institute for Earth-Oriented Space Research [3)]	NL	Boudewijn Ambrosius	R2 R3 A2 A3 A7 U3	L0c L2a-c L3cf P1ce P2abe
Astronomical Observatory, University of Porto [3)]	P	Luisa Bastos	R2 R3 A2 A4 U2 U3	L0c L1b L2a L3f P1c-e P2abde
Department of Informatics, University of Beira Interior	P	Rui Fernandes	R3 A3 U3	L2a L3f P1e P2ae
Instituto Geográfico Português	P	João Torres	A2 A3 U3	L1a L2a
Chalmers, Centre for Astrophysics and Space Science, Space Geodesy Group [3)]	SE	Hans-Georg Scherneck	R2 A2 A6 U3	P1abe P2bc
SP Swedish National Testing and Research Institute, Time and Frequency division [3]	SE	Jan M. Johansson	R2 A1 A5 U4	P1abe P2c-e
CAA Institute of Satellite Navigation, University of Leeds [3)]	UK	David Walsh	R1 R2 R3 A4	P1a-ce P2d

Institute of Engineering Surveying and Space Geodesy, University of Nottingham [3)]	UK	Alan Dodson	A1 A2 A6 A7 U3	L2a-c L3c-f P1b-e P2bde
Industry	**Country**	**Chief Scientist**	**Area of Excellence**	**Role in project**
Leica Geosystems [3)]	CH	Hans-Juergen Euler	A1 A3 U2 T1 T2 T3	P1ab P2c-e
Trimble Terrasat GmbH [3)]	D	Herbert Landau	R1 R2 U2	P1a-ce P2acd
Thales Navigation [3)]	F	Christophe Pichot	R1 R2	P1a-ce P2ad
SME	**Country**	**Chief Scientist**	**Area of Excellence**	**Role in project**
Septentrio Satellite Navigation [3)]	B	Jean-Marie Sleewaegen	R1 R2 R3	P1ab
Geo++ Gesellschaft für satellitengestützte geodätische und navigatorische Technologien mbH [3)]	D	Gerhard Wübbena	A1 A3 A5 A7 U2 U3 N1	L2b L3ab P1bd P2ce
Noveltis [3)]	F	Frederique Ponchaut	A7 A8	L3d
ARCHIMEDES LOGICA s.r.l.	I	Luca Novelli	R2 R3 A1 A3 A6 U2 U3	L2b P1bcd
Nottingham Scientific Limited [3)]	UK	Vidal Ashkenazi	A1 R2 T2	P1a-c P2de

1) The codes in the *area of excellence* refers to: **R1** Receiver design, **R2** Receiver testing and performance monitoring, **R3** Communication, receiver tools and software, **A1** Scientific analysis software and algorithm developer, **A2** GNSS analysis centre (post-processing), **A3** Real-time data processing and analysis, **A4** GNSS data centre, **A5** GNSS NRT orbits and clocks, **A6** GNSS meteorology, **A7** Ionosphere modelling, maps and tomography, **A8** Real-time ionosphere maps, **U1** Meteorology, **U2** Precise wide-area carrier phase navigation and ambiguity resolution, network RTK, VRS, **U3** Geodesy and geophysics, **U4** Time transfer, **C1** Network management, **N1** antenna calibration and testing (receiver and satellite antenna), **T1** Real-time data transmission, **T2** Interoperability aspects, **T3** Information distribution standards (e.g. RTCM).

2) The codes in the *role in project* refer to the codes in tables 1 and 2.

3) Expressed an interest to become member of the core group.

6. Communication, Promotion and Outreach

SCIGAL workshops, attended by both scientific and industrial communities, will not only ensure that the use of signal in space and user equipment meet the highest possible scientific standards and requirements, but also that European industry will be well represented in the high-end receiver market.
This project, submitted on behalf of EUREF, will benefit from the internationally recognized EUREF achievements in the field of GPS standardisation: also the tools developed within SCIGAL will be promoted as international (and not only European) standards used for receiver operations, monitoring and data exchange. This will be guaranteed, on one hand by presentations and demonstrations at international symposia, and on the other hand, by making the tools available from the SCIGAL website.
Imperatively linked to EUREF and the ETRS89, SCIGAL will provide National Mapping Agencies with the European Reference System for the next decade, which forms the backbone to which all national references are tied.
SCIGAL results will therefore be distributed to a very broad user community (scientific and public interest) and this through scientific publications, international symposia and workshops.
However, at the end, the best promotion will consist in delivering the most precise high-quality innovative products and services based on GALILEO observations.

7. Management of the Project

EUREF has shown to be a driving actor in the dissemination of GPS expertise and it was able to provide the structure for the different European institutes to cooperate, share resources, develop and pursue standards, and make publicly available tracking and auxiliary data, as well as products of various kinds.
Through the involvement of EUREF Permanent Network (EPN) partners, SCIGAL will take full advantage of the existing EPN experience concerning data sharing and data analysis. SCIGAL will be implemented progressively in a top-down approach through “Calls for Participation “ for contributing to the different SCIGAL components: receiver design and testing, tracking stations, data centres, analysis centres, etc. The project will be managed by a governing council made up from representatives of the core institutes of the consortium.