The Hellenic Positioning System (HEPOS) and its foreseeable implications on the Spatial Data Infrastructure in Greece

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Summary
In the last few years, Greece has responded to and participated in various European Spatial Data Infrastructure (ESDI) initiatives. This has made many government organizations to increasingly realize that spatial information has an important role to play in the development process of the country, mostly by providing an economic value and also contributing to several policy areas concerned with environmental and social needs. Most relevant initiatives in this direction have focused so far on developing, mainly through the Hellenic Cadastre Project, the legal framework needed to underpin the creation of a national SDI (NSDI), starting from priorities aiming to utilize many applications relying on geospatial information for the development of national or regional social benefit programs and services, and in supporting the shared objectives of various national surveying and mapping authorities.
One fundamental component of these efforts has been identified as the urgent need to establish a robust modern geodetic framework that will rely on the establishment and operation (before the end of 2007) of the so-called Hellenic Positioning (Services) System (or HEPOS), to be based on a network of some 100 continuously operating GPS reference stations which will be broadcasting and storing signal and positional correction information to be used by suitably equipped users. HEPOS will be capable of delivering centimetre-level positioning accuracy in real-time throughout Greece, thus allowing all data and observations that form the basis for geographic information systems to tie all geographical features to a common, nationally used horizontal and vertical coordinate system, for all layers of information while maintaining seamless stability for both the geodetic and cadastre frameworks.
This paper looks at the many practical implications, for the providers and users of SDI in Greece, which undoubtedly will be brought about by the improvements foreseen from the establishment of HEPOS and the combined advances anticipated by the ongoing developments of the next generation GNSS systems. The discussion will present the current HEPOS activities in Greece and the critical underlying factors which will contribute toward a convergence between the Geodesy and the Cadastre frameworks. The latter can act as a significant layer of the SDI for Greece, as well as improving efficiencies and advancing new and innovative spatial applications, such as integrated surveying techniques supported by the HEPOS network, thus allowing the modern professional surveyors to provide value-added services and expand their business activities into non-traditional surveying engineering areas.

1. CURRENT MAJOR GEOINFORMATICS ACTIVITIES IN GREECE

1.1 The Hellenic Cadastre Project

For several years now, Greece is in the process of developing a fully digital Cadastral System designed as a parcel-based land information system, serving as a legally recognized record of land ownership. The aim of the *Hellenic Cadastre* (HC) project is to establish a complete, uniform, systematic and continuously maintainable registration of land parcels in Greece and to guarantee titles, to those parcels included in the register by an adjudication process, issued according to relevant legislation (HEMCO, 1997; Dale, 1998). Its extended purpose, apart from the drawing and maintenance of a modern cadastre for Greece, is also to update the geodetic coverage and mapping of the country, the assessment and mapping of the natural resources (e.g. forests) and the creation of a land and natural environment database. This ongoing project is based on an initiative of the Ministry for the Environment, Physical Planning and Public Works (MEP^{3}W) and the financial support of the EU and the Hellenic State. Responsible for preparing strategies and providing the necessary infrastructure data

(e.g. existing topographic and aerial photography data) is the Hellenic Mapping and Cadastral Organization (HEMCO), a governmental organization under the MEP^{3}W. The development of the Hellenic Cadastre relies greatly on the collaboration between public sector and private surveying engineering firms that carry out the new data collection and other necessary tasks contracted to them by HEMCO and KTIMATOLOGIO S.A., a state-owned private sector firm responsible for the coordination of the entire project. Since the beginning of the HC project and up to date, some 340 municipalities (both in urban, agricultural and forest areas) covering about 8500 km^2 have been re-surveyed and GIS cadastral databases have been developed, operated and updated. The main products produced for these areas are:

- o Cadastral diagrams in digital form, produced photogrammetrically and completed by field surveying methods;

- o Topographic diagrams of urban areas, produced by stereo restitution in digital form and printed at a scale 1:1000;
- o Digital orthophotomaps and DTMs, at a scale 1:5000; and
- o Cadastral tables in a GIS Database, which contain all the legal and textual information concerning each land parcel and its owner. This information is derived mainly from the ownership statements submitted during the first stages of the compilation of the cadastral registers.

In the ongoing transition to their operational phase, interim regional and local cadastral offices, which are responsible for maintaining and updating the cadastral maps and registers of the cadastral areas, undertake the cadastral activities necessary for the operation and the maintenance of the cadastre, including the geodetic control network data, cadastral boundaries, buildings, topographical, survey measurements, administrative boundaries, map indexes etc. Parallel to these efforts of the public sector, private companies are developing various data products and geodatasets, which are of relevance for the Hellenic SDI. The latter is to be$_2$realized though an initiative designated as *Nagii or NaGi : National Geographic Information Infrastructure* initiative (INSPIRE, 2005), which encompasses four essential horizontal projects:

- o Conceptualization and overall design of the Hellenic SDI;
- o Data, architecture and interoperability specifications;
- o Data policy and usability issues;
- o Prototype implementation.

1.2 Geodetic Control in support of the Hellenic Cadastre and in the context of a national SDI

Geodetic control provides a common reference system for establishing coordinates for all geographic data required for the Hellenic Cadastre project and the Hellenic SDI. It provides the means for tying all geographic features to a common, nationally used horizontal and vertical coordinate system. To date, the main features of Greece's geodetic framework are conventional control stations, i.e. monumented standard surveying marks (e.g. pillars and benchmarks) that have precisely measured horizontal and/or vertical coordinates and are used as a basis for determining the positions of other points. The geodetic control component of the current framework consists of geodetic control stations and related information – the name, feature identification code, latitude and longitude, orthometric and ellipsoid heights, and metadata for each station containing descriptive data, indicators of positional accuracy, physical condition, and other pertinent characteristics for any given control point.

Since 1989 the fundamental geodetic control for Greece is designated as the *Hellenic Geodetic Reference System 1987* (or EGSA '87, as it is termed from its Greek acronym). Mapping and surveying works are connected to EGSA '87 by tying all new projects to previously established control points that are part of the EGSA '87 control framework. EGSA '87 is a non-geocentric datum that is effectively defined by the coordinates of the key geodetic station at the Dionysos Satellite Observatory (DSO) near Athens. It uses the *Geodetic Reference System 1980* (GRS80) ellipsoid, whose axes by definition are parallel to those of the ITRF89 system and its origin is transformed relative to the geocenter and coincides with the ITRF coordinates of the central pedestal at DSO, so that the ellipsoidal surface is most optimal for Greece. As its projection system EGSA '87 uses a Transverse Mercator projection consisting of one zone, with central meridian at 24° and a scale factor of 0.9996 throughout the zone, and with the remaining required parameters being the same as in the Universal Transverse Mercator (UTM) projection.

Although, the current geodetic framework realized by the EGSA'87 reference system has served its original purpose up to now and it still continues to be sufficient for many geodetic and topographic needs, it remains a reflection of Greece's development needs and of the available technology available at the time it was established (e.g. with many control points sited on hill- and mountain-tops for inter-visibility). It is essentially a passive framework used mainly by surveyors to control diverse types of mapping, engineering and infrastructure projects throughout Greece. With today's standards and the modern requirements to meet the community's wider needs for positions, and the availability of satellite technologies that nowadays provide real-time, active and accurate positioning information to the surveying industry and the wider user community, one major drawback is that the EGSA'87 system essentially constitutes a "static datum" as it does not account for the effects of the regional geodynamic motions on the geodetic control stations. For a country such as Greece, which is subject to the effects of significant ground movements due to earthquakes and crustal deformations caused by plate tectonics, the ability to survey and record these movements in order to maintain accuracy of the geodetic system and the spatial accuracy of the geodetic control stations is an important task that today cannot be overlooked.

In the context of the Hellenic Cadastre, geodetic control information plays a crucial role in developing all cadastre related data and users' applications data, because it provides the spatial reference source to register all other spatial data. In addition, it is used to plan surveys, assess data quality, plan data collection and conversion, and fit new mapping data into existing map coverages. Hence, accurate geodetic control is required in order to ensure spatial consistency, accuracy, timeliness, and ease of access to spatial reference in support of the needs of the Cadastre project and to assist in matters of land related strategies on key areas of economic development, environmental protection and well being, and to enhance the potential of the cadastral data for multiple uses.

For all these reasons, it is rather obvious that a modern geodetic framework is fundamental to the HC project's aims for building a Spatial Cadastre Database having geodetic integrity and relaying on accurate coordinates to support surveys and to underpin the management and administration of land and the physical environment. Therefore, as we move to a world where new positioning technologies allow us to rapidly determine the accurate position of features and points, we are moving closer to the concept of everything 'geodetic': that is, the development of a seamless survey accurate cadastre (geodetic cadastre) and all spatial datasets in terms of a common geodetic system. This spatial framework will allow the definition of land rights, and changes in land use and settlement to be recorded accurately with the ability to monitor the effects and over time, and to support topographic mapping, hydrographic charting, geodynamic monitoring etc., that is all activities that are central to the establishment of a National Spatial Data Infrastructure (NSDI). However, in such a modern NSDI framework, geodetic control needs to be based on a coordinate reference system that is fully compatible with the new generation of positioning technologies, including GPS and Europe's upcoming independent satellite navigation system GALILEO. Hence, as part of the latest development efforts within the HC project, it has been decided that an Active GPS Control Network for Greece will underpin such a new coordinate reference system. This will be realized through the so-called *Hellenic Positioning System (HEPOS)*, a network of permanent, continuously operating GPS (and future GALILEO) stations, such that a user anywhere in Greece would have access to, and would be at most 70-100 km from, such nearby stations which will facilitate a real-time centimetre-level positioning capability using single GPS receivers. This active control network will enable the definition of a "dynamic datum" for Greece, as it is further expanded in the next section of this paper.

2. THE HELLENIC POSITIONING SYSTEM (HEPOS)

2.1 Objectives and Scope

The project of the Hellenic Positioning System (*HEPOS*) is an initiative, by the Hellenic MEP W, with the aim to establish a uniform multifunctional DGNSS-based reference stations network, which will cover the approximately 132 000 square-kilometres of Greece's territory. These stations will be referenced on the common *International Terrestrial Reference Frame* (ITRF), or to be more precise, on the *European Terrestrial Reference Frame (ETRS)* and will be collecting continuous GPS observations following accepted unified data formats and international standards, such as those already established by the *International GNSS (Global Navigation Satellite Systems) Service* or IGS (formerly the *International GPS Service*), the *European Reference Frame* (EUREF) sub-Commission of the International Association of Geodesy (IAG) which is responsible for the maintenance of the ITRF-based *European Reference System* (ETRS89), and *Eurogeographics*, the umbrella organization of nearly all European National Mapping and Cadastral Agencies, which focuses on aspects regarding reference datasets, improved metadata services, and specifications, policies, and procedures necessary to develop sustainable solutions for building the European SDI.

In this broader context, HEPOS is planned to provide a ground-based GNSS infrastructure for differential correction of the GPS/GNSS satellite data for real time users on a regional and local extent. The accuracy of real time positioning will be in the cm-accuracy range. This means that a *"full scale accuracy*" integrated infrastructure will be available for all categories of GNSS-based HEPOS users. Accordingly, KTIMATOLOGIO S.A. has assumed the role of establishing the necessary survey-grade, real-time GPS reference station technology, as an extension of ongoing work currently under development for the Hellenic Cadastre, and thereby supporting, in cooperation with academia, other government departments and transfer to the private sector, the implementation of future diverse GNSS applications through HEPOS. The first step in this direction is focussed on the establishment and operation of the HEPOS network segment, which is expected to be implemented and be fully tested and operational by the end of 2007. At the same time, it is planned that the HEPOS development activities, at first, will go in parallel with the establishment of precise ties to ITRF (ETRS) for all HEPOS stations and a sub-set of some 2500 other geodetic stations (as necessary) from the existing geodetic control network, leading eventually to the adoption of ITRF and the European Terrestrial Reference System '89 (ETRS89) as the new fundamental coordinate reference system for Greece.

2.2 HEPOS Key Features and Requirements

The overall design of HEPOS has borrowed many of the key features of similar systems currently operating or being developed for other regions in Europe and worldwide. Typical such examples are: the planned *European Positioning Determination System* (*EUPOS*), which aims to establish a uniform multifunctional DGNSS basis infrastructure in Central and Eastern Europe; the already operational "German National Survey Satellite Positioning Service" (SA*POS*); the Swedish network of permanent GPS reference stations SWEPOS; the Automated GPS Network of Switzerland (AGNES) and other similar non-European infrastructures, such as the US network of *Continuously Operating Reference Stations* (CORS) and Australia's Permanent Network (APN), regional VRS networks (e.g. GPSNet, SydNet) and the on-line processing service known as AUSPOS.

The locations of the active permanent reference stations will be selected primarily so that the distance between adjacent stations could not be greater than about 70 km, so that complete *HEPOS* functionality will allow the large variety of users to determine their position with required accuracies at various levels (from several millimetres or a few centimetres to a few meters in real-time, depending on the intended application). Initial station network pre-analyses have indicated that some 100 such stations will be required in order to fulfil this requirement (Fig. 1). As part of these analyses, current investigations focus on examining whether, which and how the existing infrastructures, e.g. continuously operating GPS stations already serving other purposes, such as being part of the geodynamic monitoring networks in Greece, should be best integrated into the *HEPOS* network, thus broadening its functionality beyond the typical provision of support for positioning and navigation tasks. The positions of all HEPOS stations will be computed in conjuction with GPS data from several IGS permanent stations located around Greece which will be used to connect the network to the ITRS and realize ITRF specific epoch coordinates.

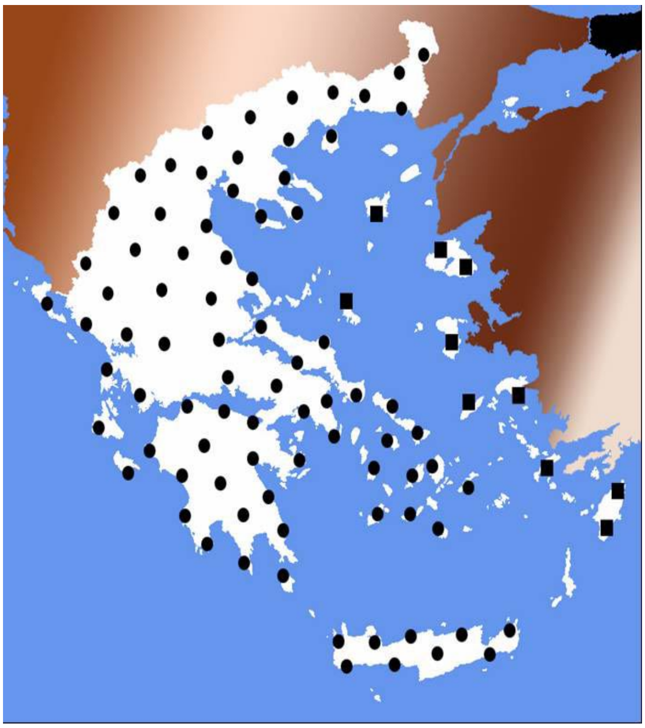

Figure 1 *Schematic coverage of the stations comprising the HEPOS network*

Apart from the stations, other essential components of the system are the HEPOS Control Centre(s), the Telecommunications Network Sub-system and the User Segment that concerns all the services to the user community that will be collecting and processing GPS information for exploitation (Fig. 2).

A key component of the future HEPOS services will be one or more *HEPOS Control Centres* (HCC) that will be established in order to deal with the tasks of planning, establishment and maintenance of the entire HEPOS network of stations. The main HCC will be established in Athens and, as needed, a few more secondary HCCs are likely to be established in major cities, so that to provide the necessary backup functionality and the necessary controls for the integrity of the entire network of stations. Respectively, beyond these activities, a significant role is foreseen for the *HEPOS Service Centres* (HSCs), whose most important tasks will be the following:

- Provide adequate and timely information to the users about the operational status of the network
- Carry out software and hardware tests in support of the HEPOS functionality and of the interest to the HEPOS user communities
- Increase awareness among potential users
- Keep contact with the various mapping authorities and other interested governmental bodies, as well as the HCCs
- Maintain an official point of contact with the HEPOS providers and users throughout Greece
- Follow the international development trends and contribute to the HEPOS continuing state-of-the-art developments

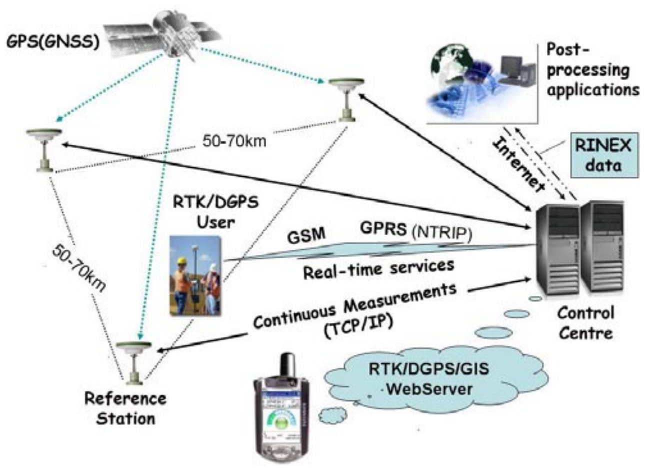

Figure 2 *Basic functional components and services to be provided by HEPOS*

- Contribute to the HEPOS application developments in Greece by technology transfers of the HEPOS-generated research, development activities and special products
- Organise educational and training courses for the HEPOS technical staff and for the benefit of the users on the HEPOS applications and products

Overall, HEPOS is anticipated to serve both as a system and as a service for the regional realisation of all future GNSS (i.e. GPS, EGNOS, GALILEO) applications meeting the positioning requirements of a wide spectrum of users. The main characteristics of the system will be the high precision, the integrity/reliability and the homogeneity of system performance throughout the area that will cover. Establishing a capability for rigorous positioning capability within any area in Greece would offer many practical and scientific benefits including the following:

- Gaining reliable access to a stable system for both post-processing and real-time positioning purposes
- Costs savings to surveyors – since no base station will be needed; only one surveyor in the field
- Greater data integrity over time
- Making widely available, for the geodetic community to use, the core products of the HEPOS network, such as
  - o Daily 24-hour GPS carrier phase and code observations, on both frequencies, for all satellites in view;
  - o GPS/GNSS navigation messages and status information;

  as well as higher-level products that could be derived, such as, for example:
  - o Highly precise satellite ephemerides;
  - o Earth rotation parameters;
  - o Ionospheric and atmospheric information; and
  - o Coordinates and velocities of the permanent GPS stations.

3. IMPLICATIONS OF HEPOS IN THE SURVEYING PRACTICES

3.1 The Virtual Reference Station (VRS) Network Concept

The use of the HEPOS system will be based on the so-called *Virtual Reference Stations* (VRS) *Network* concept (Landau et al., 2002; Wanniger, 2003), which is an extension of the real time kinematic (RTK) technique, developed for GPS surveying and other forms of high accuracy positioning. With RTK, one can establish a reference/base station at a precisely known point and broadcast the data from the reference station to one or more roving receivers using the short wavelength of the GPS carrier for greater precision.

At the roving receivers, a computer processor subsequently combines the reference station data with the rover's data of a few seconds duration in order to fix the ambiguities associated with the GPS phase data observable and compute the length of the GPS baseline and the relative coordinates in latitude, longitude and height between the reference and rover stations. RTK is a technique for precise relative measurements over short baselines (<20 km) that enable the roving receivers to be positioned in very near-real time (within a few, usually less than 3 sec of the observation time) with accuracy better than a few centimetres relative to the reference station, thus revolutionizing the productivity achievable with GPS.

One main drawback, which the RTK techniques suffer from, is the necessity to have a reference station (RS) in the vicinity of the user, as well as the fact that the error solution degrades and the accuracy suffers as the user moves farther from the RS. In practice, usually the distance from the RS when using RTK should be generally no more than 10 km, which is significantly different from differential GPS (DGPS) operations, where distances to a nearby RS can exceed several hundred kilometres. This means that if one wants to provide an area of 1000 sq. km with a reliable RTK service, one has to have installed some 2500 reference stations. This drawback of the RTK techniques can be overcome by a network of *Virtual Reference Stations* (VRS), which along with a number of well-developed methods allows the use of a moderate number of RS, providing the same full coverage in an area of interest (Vollath et al., 2000).

In the VRS concept, the established permanent reference stations feed GPS data to a central processing computer via a computer network.

The central processing computer can use the reference station data to model spatial errors that limit GPS accuracy and generate appropriate corrections. In turn, a roving receiver through a mobile communication link (e.g. GPRS, GSM) with the central processing facility supplies its approximate position (based on its current GPS navigation position) and requests appropriate corrections for the instant of its own observations.

The central processing computer then generates corrections as though there was a reference station at the coordinates of the rover's approximate position and the rover is positioned relative to this *virtual reference station.* In practice, some irregular physical effects could typically occur in this process.

For example, significant errors may arise from local troposphere or turbulent ionospheric conditions, and therefore these may still be difficult to be determined by a reference station network with certain and restricted spatial capability. However, even if these higher order errors cannot be determined completely by the reference station network, it is obvious that their magnitude would be mostly a function of the distance from the closest reference station. In effect, the Control Central Server, using the same communication link, sends back valid correctional data to the user using the well-known optimised *Radio Technical Commission for Maritime Services* (RTCM) correction messages format (RTCM, 2004).

This process defines accurately the user's actual position. More importantly, this complete task is effectively achieved at the 'press of a button' (e.g. less than 3 sec) in the field. Such real-time kinematic GPS technology enables almost any survey work to be carried out within the entire network coverage area, with homogeneous position accuracy to the centimetre level. It is obvious that this (extended-RTK) VRS concept takes

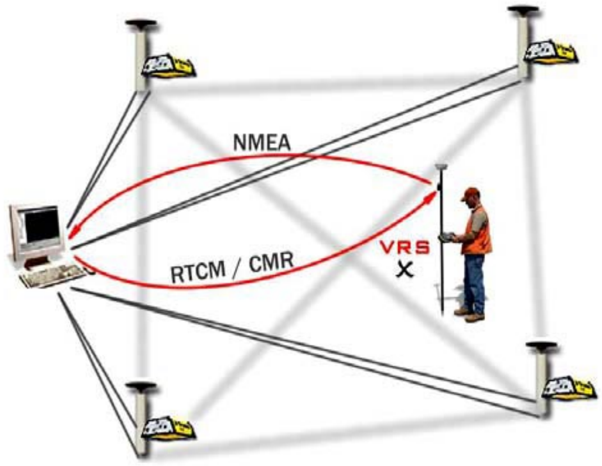

Figure 3 *The VRS measurement process*

the productivity increase one step further by overcoming four main limitations of the traditional RTK techniques:

1 Surveyors no longer need to establish and run a GPS receiver and a radio-link at their own temporary base station every time they want to conduct an RTK survey operation in the field.
2 The Network Reference Stations allow to eliminate/ reduce the systematic errors in the reference station data, i.e. making possible to increase the distance to the reference station for RTK positioning while reducing the initialization time required in the field by a suitable RTK-capable receiver.
3 The use of today's mobile communication technology (e.g. GPRS, GSM) overcomes the limitation of the range of radio communications conventionally used in the RTK techniques.
4 Multiple reference stations increase the redundancy and thus the confidence in the resulting rover positions and the reliability of the overall system.

Typical areas where the HEPOS-based VRS approach would be particularly viable are large metropolitan areas, such as around large urban centers where high development activities are usually taking place, and other regions (e.g. less urban or rural areas) where there are high cost activities (e.g. precision farming, mining, cadastre mapping). Furthermore, once the HEPOS VRS infrastructure is in place, other processing approaches will also be useful in certain situations. A typical example would be an on-line web service whereby a HEPOS user will simply need to gather data with a single GPS receiver and submit that data to a HEPOS web site where the data would be suitably post processed, e.g. with precise GPS orbits (i.e. from IGS) and together with data from the nearby HEPOS VRS stations, and the results will be e-mailed back to the user. The achievable accuracy, in this case, would depend mainly on the amount of data gathered and submitted by the user. In an alternative approach, the user may request VRS stations data and other HEPOS data complementary to the rover receiver data and perform all the computations of the rover position using one's own software.

These HEPOS on-line approaches may offer a viable logistical alternative to the traditional approach of connecting to sufficient geodetic stations of the local geodetic networks, since it may give a comparable accurate result, while requiring significant less field time for travel and for GPS baseline observation (occupation) time and hence allow for greater efficiencies to the data producing organizations using the countrywide HEPOS solution for RTK surveying tasks.

3.2 Anticipated Impacts and Issues

The aforementioned approaches to be made possible by the HEPOS infrastructure would certainly have a number of obvious impacts on the current surveying engineering practices in Greece. These impacts need to be addressed prior to the date the system is planned to be operational (i.e. by the end of 2007), since they will generally have broad implications in the management of the future spatial data to be collected.

Firstly, once the HEPOS network of stations is in place, a careful study will need to be conducted in order to investigate the implications of the achievable accuracies in the HEPOS-based positions and to familiarize the future HEPOS users on issues of changing methods and evolving technology approaches to the new HEPOS-based measurement challenges. This can be done e.g. by issuing relevant technical guidelines detailing the conceptual and operational elements of this new measurement-based spatial information system and how this could meet the requirements of any given positioning project and especially how to aid in the organization of land boundary information and future spatial information developments.

Secondly, the HEPOS network of stations once they are implemented, tested and fully operational, will lead to the realization of a "zero order" active geodetic control network that will provide Greece with a local implementation of global coordinate system (e.g. ITRF), including the capability to account for the crustal deformations across the country, primarily due the effects of the tectonics of the broader boundary region between three major tectonic plates, the Eurasia, Africa, and Arabia plates which surround the relatively small Aegean Sea plate. It is the relative motion of these tectonic plates with respect to each other by about 2-5 cm/year that are responsible for the seismotectonics regimes of Greece. Hence, the ability to survey and record these movements to maintain accuracy of the geodetic "fabric" on which all geospatial data is based is an important task. To this end, the HEPOS network will allow to interpolate the dynamics of this geodetic "fabric" in space and time. This will alleviate the existing internal distortions of the current datum, which have been steadily increasing at the rate of up to half a metre per decade due to earth deformation, with all the consequences on the current geodetic positioning applications. This would be especially so on the use of GPS, which with its current potential to efficiently meet existing survey accuracy requirements over very long distances, has significantly increased this problem, since modern GPS observation and processing techniques allow accuracies better than 0.1 ppm which, in many parts of Greece, is equivalent to a few months' earth deformation. Therefore, the HEPOS infrastructure will enable a host of new and a wider range of spatial applications to be supported in a manner that will be consistent with the current international standards and best practices underlying a "dynamic datum" that includes the motion of control stations and coordinate axes in the datum definition.

Thirdly, through the use of HEPOS, it is planned for Greece, like many other European countries, soon after the establishment of HEPOS to move into adopting a new geocentric datum, realized through a specific ITRF solution (e.g. ITRF 2000) and the GRS80 ellipsoid. This adoption will allow closer integration with international coordinate frameworks, navigation systems, scientific applications and routine spatial data management. On the other hand, as a result of this change, there will be the immediate need to consider the implications for the degree of maintenance of the old datum (i.e. the EGSA '87) in all its three dimensions.

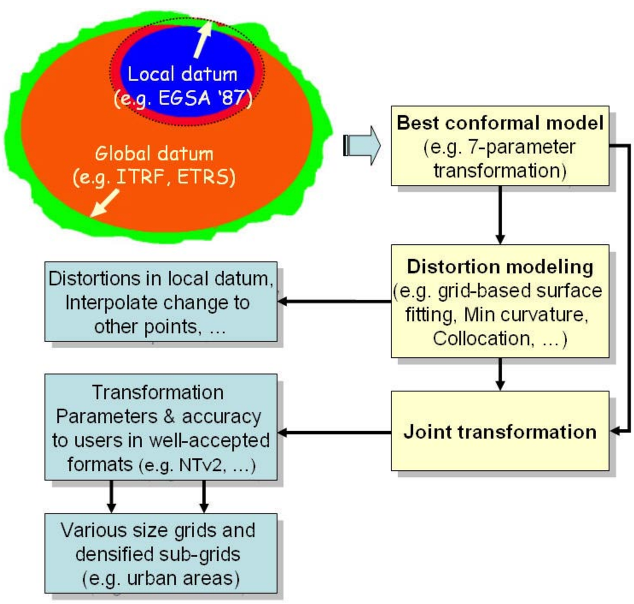

Figure 4 *As a HEPOS-follow up, transition to a geocentric datum for Greece.*

The timing of this datum change can be difficult. To begin with, the implementation of a new geocentric datum for Greece will involve an approximate 200-metre change from existing EGSA '87 coordinates. Furthermore, in the HEPOS era, users wanting high accuracy will find that the old datum does not meet their accuracy needs. Therefore, users that are about to make large investments in spatial data will want the datum to change before they invest in the use of HEPOS rather than just afterwards. On the other hand, users that have already made large investments in the use of spatial data referenced on the EGSA '87, or users that have low accuracy needs, will want the old datum preserved as long as possible. If the datum does change, without making available the necessary tools to be able to convert from the old "static datum" to the new "dynamic datum", a large majority of users may refuse to switch over thus increasing confusion in the spatial data marketplace. To avoid such a situation, current efforts, as part of the ongoing HEPOS developments, focus on a scheduled countrywide GPS campaign, to be held in 2007, with the aim to compute ITRF coordinates for a large set of stations of the existing geodetic control framework of the country. The number, distribution and accuracy of these common points and the transformation technique adopted will determine the achievable accuracy of the old-to-new datum transformation.

Generally speaking, the greater the accuracy required, the more common points are needed. Preliminary studies have indicated that about 2000 to 2500 such "common points" of known coordinates in the old and the new earth-centered datum will be required in order to depict the true relationship between the two datums. This will allow deriving a National Coordinate Transformation that would model the differences between the old EGSA '87 reference system and the ITRF-based new Geocentric Datum of Greece (GDGxx). The results will be used to produce rigorously computed transformation parameters to enable EGSA '87 dependent spatial data to be brought onto the ITRF-based geodetic datum and to be integrated into Greece's SDI and in the longer run facilitate the exchange of compatible geospatial data at local, regional, national and European levels. Considering that the existing geodetic framework has variable quality and that Greece does not have a continuous landmass, a major issue arising from such an action is the requirement to develop and implement a nationally consistent transformation process. A preliminary investigation by the author of the available transformation options has identified that the simplest and, in terms of accuracy, the most suitable method for Greece's situation could be a grid-based transformation strategy based on a 7-parameter transformation complemented by a distortion modeling approach (fig. 4), very much like the approach that has already been used successfully for similar problems in Canada, the USA, Australia and in Europe (cf. e.g. Dewhurst, 1990; Collier et al., 1998). The most notable advantage of this approach is that it could be possible to supply to users the transformation components and their associated accuracy on a regularly spaced grid. The transformation of any point within the grid could then be achieved by simple interpolation steps from the surrounding grid nodes. Furthermore, different grid densities can be used in different areas (e.g. urban areas) to accommodate changes in the pattern and spatial variability of the transformation components.

3.3 Tangible Benefits to the Surveying Community

The establishment of HEPOS would be an unparalleled undertaking for Greece, above and beyond the technological tools that the GPS, or the broader GNSS technology represents today. The system's main aim is to offer to Greece's surveying community a delivery of services to meet its most important needs: i.e., acquiring quality survey information in a timely manner. While it is still too early to foresee all the future possibilities and developments that will be offered by the HEPOS network, we can safely assume that this initiative will have ramifications for all key producers and users of geographic information throughout the country, not least in unleashing a host of new geoinformatics applications.

By implementing the HEPOS system as previously described, will enhance the quality of the Hellenic Cadastre and other surveying works in Greece while decreasing the time it takes to produce the required future surveying data and geographic information which is important for developing a modern NSDI infrastructure. Installing the extensive permanent GPS network of continuously operating HEPOS stations would provide a permanent consistent framework for all forms of future surveys. The base stations will provide access to permanent, accurate positional data accurate to within a 1-2 cm anywhere in Greece and at any time. This will enhance the quality of the control data and also eliminate the need for local control monuments to be searched for and occupied, thereby saving considerable time and resources. In the longer term, this will allow the provision and use of the surveying infrastructure to moved from a reliance on conventional ground marks to increasing reliance on the permanently running HEPOS stations. With the addition of airborne GPS surveys and acquisition of high-resolution photography, which is scheduled as a follow up project in early 2007, these time savings are anticipated to increase dramatically thereby expending the full development of the Hellenic Cadastre and the Hellenic SDI.

HEPOS will make possible for the broader surveying community to supplement its personnel resources for control surveys and to utilize them to perform concurrent operations thereby increasing the efficiency of surveying operations and saving, by conservative estimates based on the experiences from similar European VRS systems, as much as 15% to 20% in the amount of time it would take to complete the horizontal control for any typical survey project. Beyond these benefits, HEPOS will position the surveying industry to utilize effectively the rapidly developing technological advances in the modern VRS-related surveying methods. These methods, will allow surveyors the ability to enhance their capabilities in more demanding applications, such as real time mapping, thereby having an even greater impact on the ability to increase production through a more efficient mapping process, such as, for instance, in the control component of surveys for road and bridge design and photogrammetric control surveys, GIS applications, "smart" highways applications, monitoring and mapping the location of vehicles, Location Based Services (LBS) etc.

On the other hand, it is also worth mentioning that, while the virtual approaches to surveying infrastructure to be afforted by the HEPOS network will bring new opportunities, it may also raise some problems in the short or medium run. For example, surveys from distant HEPOS base stations in and around existing geodetic networks of ground marks could lead to a mixing of varying levels of absolute and relative accuracy. Therefore, the providers and users of the surveying infrastructure would need to be aware of the likely problems of such mixing and its effects will need careful consideration to ensure that the final positions will have sufficient absolute and relative accuracy to meet the requirements of any given project. As a consequence, for users, would be important to decide on the most appropriate approach (i.e. HEPOS-based operations alone vs. combined with conventional surveys) for a given set of circumstances and project requirements. Usually this matter will boil down to the most efficient logistics approach, which often comes down to the time duration for a given survey project when using one approach or another. In some remote areas, web HEPOS-based post processing relative to distant base stations may turn out to be more efficient than surveys connected to the closer ground marks infrastructure. On the other hand, in many high activity areas, such as in urban environments, HEPOS-based VRS techniques will undoubtedly become increasingly viable. In the less dynamic rural and regional areas, base station approaches may not be as viable and existing ground mark infrastructure may continue (at least for sometime) to be the best way to service the standard RTK and fast static surveys that are likely to continue to be the preferred approach in most cases.

4. SUMMARY AND CONCLUSIONS

Spatial data infrastructures need to be built on a uniform reference geodetic network if they are to be readily assembled without any difficulties or problems occurring for national, regional and global applications. When spatial data infrastructures are built on a well defined geodetic framework they can be readily integrated nationally or combined for a regional or local perspective without positional confusion, overlap or duplication. These compatible data sets can then readily be integrated and used for development purposes, for contributing to several policy areas concerned with environmental and social needs or for emergency management operations to reduce the impact of natural or man made hazards.

The ultimate aim of the upcoming HEPOS project is to develop a country-wide satellite based geodetic infrastructure capable of providing location services with a high precision, easy access, in real-time and in a cost-effective manner. Furthermore, it will contribute to the orderly transition to a dynamic geocentric geodetic datum for Greece, to be used for all future spatial data. Many benefits, public and private, have already been identified in establishing this permanent reference station technology infrastructure. Ubiquitous availability of real-time, survey grade GPS in the field can lower spatial data collection costs through reduced crew sizes and increased productivity while providing increased reliability in precision and accuracy of field measurements for many uses, including survey tasks requiring accuracies at low error levels (<1 cm). More importantly, as users will be increasingly moving to digital technology for management of spatial data, the transition to a fully dynamic datum, to be afforded through HEPOS and its associated infrastructure, will become more practicable.

The HEPOS infrastructure will be based on a combination of cutting-edge spatial technologies, advanced communication and information management systems, and HEPOS will undoubtedly further promote corresponding developments in these areas. Apart form its original intended purpose to support geoapplications, the HEPOS system is anticipated to trigger numerous other research and development opportunities relating to real-time environmental and ecological monitoring, rescue and emergency operations, engineering structural monitoring, GPS atmosphere studies, natural hazard surveillance, fleet management, precision farming and intelligent transportation management, to mention just a few. Hence, it is expected that its successful development will soon be followed by a rapid market penetration in a wide range of engineering, scientific and commercial applications.

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