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NATIONAL REPORT ON GEODESY

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PREFACE

This report outlines some Spanish activities in Geodesy for the period 1999 to 2002. It has been prepared for submission to the International Association of Geodesy (IAG) on the occasion of the XXIII General Assembly of the International Union of Geodesy and Geophysics in Sapporo, Japan, June 30 - July 11, 2003. It is issued on behalf of the Spanish Committee of Geodesy and Geophysics

In the report the main activities in Geodesy developed in Spain in the period 1999-2002 by different Institutions are presented. This Institutions in alphabetic order are.

1.- Hydrographic Institute of the Navy. (Instituto Hidrográfico de la Marina). CADIZ
2.- Institute of Astronomy and Geodesy (Instituto de Astronomía y Geodesia), MADRID.
3.- Institute Cartographic of Catalonia (Instituto Cartográfico de Cataluña). BARCELONA.
4.- National Geographic Institute (Instituto Geográfico Nacional). MADRID.
5.- Royal Institute and Observatory of the Navy. (Real Instituto y Observatorio de la Armada). San Fernando. CÁDIZ.
6.- Valencian Cartographic Institute (Instituto Cartográfico Valenciano). VALENCIA
7.- Politecnical University of Valencia. (Universidad Politécnica de Valencia)

The information provided by the Institutions has been incorporate in the Report, and due to the quantity and diversity of works done these has been resumed, giving for each Institution a list of the activities followed by the list of papers published in the period.

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Introduction

The Instituto Hidrográfico de la Marina, located in Cádiz, was established by law dated 30th December 1943, as an organization within the Navy. A later Law on arrangement of Cartography (7/1986) specified the responsibilities of the Instituto, its task being the information and maintenance of basic Nautical Cartography.

The aim of the Instituto is to look after the safety of navigation, in the sense of collecting and diffusing information on the sea and the coast, and to foster the development of Nautical Sciences. To achieve this goal, the Instituto has six main responsibilities:

· Hydrographic surveys and studies on submarine relief in Spanish coastal and maritime areas, as well as other areas assumed in compliance of its agreement with the International Hydrographic Organization (IHO), where it represents the Government of Spain.

· Systematic observation and study of tides and currents, temperatures and acoustic and electromagnetic propagation in seawater, meteorology and, in general, any physical feature which may affect navigation.

· Development of Nautical Charts, books and documents as aids to navigation, and their printing and distribution.

· Collection of data and news on alterations in the environment, aids to navigation or dangers to the same, which will be disseminated as Notices to Mariners, for the updating of nautical charts and publications.

· Determination of features and specifications of nautical instruments used on board Navy vessels, certification and validation of them.

· *Carrying out geodetic and hydrographic works of interest for the Navy*, as well as research programmes assigned by the Navy Research and Development Directorate.

Maintenance of the Hydrographic Control Network

The ***Hydrographic Control Network (RCH)*** is a geodetic network used to control the positioning during a hydrographic survey. It is composed of geodetic stations called ***RCH stations***. Currently, this network comprises some 1200 stations. The coordinates of these stations, as well as some other relevant data, are included in the so-called *RCH* station report, which is filed and stored in a database by the IHM *Sección de Fotogrametría y Geodesia* (Geodetic and Photogrammetric Section).

RCH station coordinates are determined by means of *moving geographic positions* using two kinds of procedures: *Conventional Procedures*, by measurement of angle field and/or distance, reduction of them to the ellipsoid and solution of the so-called ***main geodetic problems***, also known as *Direct Problem* and *Inverse Problem*; and *Spatial Technique Procedures*, using the satellite positioning system named *Global Positioning System, GPS,* which allow for the output of coordinates in system *ETRS89*.
RCH will be based on the stations of the ***Conventional Geodetic Network, ROI*** and ***National Geodetic Network by Spatial Techniques*** **(*REGENTE)***, established by the *National Geodetic Institute (IGN)*, or on *RCH* stations from surveys antedating current work in progress.

Measurement of field of distance and/or angle, to obtain the features of the ellipsoid used in the solution of the *main geodetic problems*, are carried out using several techniques like Polygonal, Radiation, Triangulation and Trilateration.

<u>Transformation parameters from ED50 to WGS84 in the Spanish coast</u>

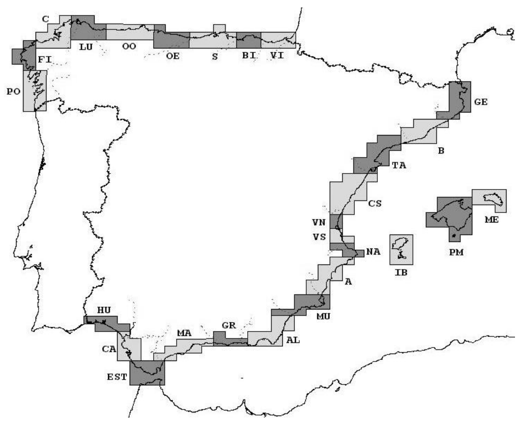
The simultaneous presence of datums ED50 and WGS84 force any cartographic production or positioning system to work on data referred to any of the two datums and produces a final result in just one of them. The current trend in production at the *Instituto Hidrográfico de la Marina* is to publish nautical cartography referenced to WGS84 datum, which is necessary for the generation of ENC (Electronic Navigational Chart).

Also, Hydrographic surveys are carried out under WGS84. The quality of final products relies on the quality of the transformations of items from one datum to the other, which has prompted a study on the most efficient methods of transformation. This study includes a number of observation cruises with GPS receivers to generate double sets of coordinates for the calculation of transformation parameters. The Instituto Hidrográfico de la Marina has finished these cruises, started in 1993.

The distribution of the areas which parameters are computed for is done on a province level along the whole Spanish peninsular coast, and at the island level for the Balearic Islands. Within each province, those sheets in the National Topographic Map scale 1:50000 inside its demarcation are selected. This set of selected sheets form a zone for the computation of parameters.

To cover the needs of the IHM regarding transfer of geographic files of nautical cartography in ED50 system into WGS84 datum, each chart has been assigned one province or island zone of parameters.

More general parameters have been computed for those nautical charts that, due to scale, comprise more than one province or island zone. Consequently, each nautical chart in the IHM Cartographic Project has been assigned specific transformation parameters.



Zones distribution, Molodensky 7 parameters model

A small statistical survey has been carried out to know the performance of the parameters on the limits of each zone with regards to the contiguous zone, resulting in mean discrepancies of 36 cm in longitude, 47 cm in latitude y 186 cm in height.

<u>Publications:</u>

Millán, J., (2002): Parámetros de transformación ED50 a WGS84 en el litoral español

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SUMMARY OF Results description

Gravimetry and inverse problem (A. G. Camacho et al.):

Data reduction (tidal correction, instrumental sensibility, marine data) - Fit of traverses (drifts, recording jumps, scale adjustment, data quality) - Terrain corrections from digital models - Fit of regional trends (robust methods) - Covariance analysis and least squares prediction of gravity anomalies - Gravity inversion (non linear inversion, exploratory methods, inversion of noisy data with blunders, fit of linear trends, fit of models with positive and negative density contrasts, optimal balance between smoothness and fitness, 3-D models, graphical presentation of 3-D models) - Reduction of absolute observations.
APPLICATION WORKS: Mainly gravimetric studies of: - Archaeological rests (buried walls, Palaeolithic caves and crypts). - Karstic structures. - Volcanic areas: - Canary Islands Azores Islands - Decepcion Island (Antarctic)

Geodetic boundary value problems (J. Otero et al.)

The mathematical analysis, from theoretical and practical points of view, of some boundary value problems is one of the topics of Physical Geodesy. In the theoretical respect a new existence and uniqueness of solutions theorem has been obtained for the scalar Molodensky boundary problem (Otero and Sansò 1999). The theory and analysis of free boundary value problems has attained certain popularity in Geodesy in the last 20 years, being considered as a sort of reference theory providing a sound scientific background to the problem of determining the figure of the earth and its gravity field. In this framework an effort has been done to come to a solution of the most relevant problem, namely the so-called scalar geodetic boundary value problem (introduced by Sacerdote and Sansó in 1985), under the most general conditions of regularity of the boundary values. In this paper we give a result that, in the authors' opinion, seems to be the most natural and somehow a point of arrival of all the work done in the field. In fact the basic theorem proven in this paper guarantees a solution for the (modified) scalar geodetic boundary value problem in spherical coordinates under the conditions that the gravity g and that the potential v belong to the Hölder spaces H_α and $H_{1+\alpha}$, respectively.

A comparison between various approaches to solve some classical geodetic boundary problems, including Sanso's change of boundary method and the analytical continuation method, has been carried out in (Otero and Auz 2002). From the basic idea of the Molodensky shrinking we propose an alternative variational approach to solve some linear geodetic boundary problems. We show that the variational approach solution and the solution by analytical continuation are formally the same. The essential difference is that no use of downward analytical continuation is made in the variational approach. Rather, upward harmonic continuation from the Bjerhammar sphere is what is needed to explain the terms of the derived series. In this way the Marych-Moritz' s solution could be now correctly interpreted. In addition, this upward harmonic continuation allows that one can guess some linking between the change of boundary method and the variational approach, and this relation is also studied in this paper.

The precision that can be obtained with the actual satellite positioning techniques justifies the assumption that the earth surface is known. Therefore nowadays the GPS-gravimetric boundary problem has become very relevant being one of its applications the determination of geopotential numbers (the physical measure of height above sea level). This is a non-linear and oblique derivative problem. In (Auz and Otero 2002) once the problem is linearized we solve it by means of Sansò's change of boundary method leading to a series solution avoiding a downward analytical continuation. The first order solution is compared with the gradient solution given previously by Moritz (2000). Using a Taylor expansion both results are shown to be formally the same.

Direct geodetic problem and UTM coordinates (J. Otero et al.)

Both in the determination of the latitude in the direct geodetic problem, and in the obtaining of the geodetic coordinates from the UTM coordinates we are led to solve a similar non linear equation. In (Bermejo and Otero 2002) we propose to use the Newton iterative method for solving both problems. Numerical examples show its fast convergence and accuracy. In (Bermejo and Otero, 2000) the maximum angular distortion for the UTM projection in finite approximation is analyzed. This maximum angular distortion is computed along parallels south, center and north of the Iberian Peninsula and along meridians close to the central meridian.

Time series analysis methods (J. Otero et al.)

Time series methods are of basic importance for the analysis of geodetic and geophysical time-dependent and large data sets. In (Otero and Sevilla 2002) we sketch the theoretical foundations of some stationary processes more frequently used, like moving average, autoregressive and ARMA processes. In addition, we give two examples quite different: the first one is a series of ellipsoidal heights obtained from GPS observations in Lanzarote's permanent station; the second, is a series of orthometric heights corresponding to the leveling network of Milan's Cathedral.

Theory of geodetic linear models (J. Otero)

The paper (Otero, 2000) is a contribution to the theory of geodetic linear models with rank deficiency equal to 1: we give the pseudoinverse matrix of the design matrix (which is of incidence type), and making use of the Gauss-Markov theorem we obtain the BLUE of the parametric functions associated to the rows of the design matrix (the true values of the observed magnitudes). This BLUE is interpreted as a weighted mean of all of its possible uncorrelated determinations using pairs of observations including the direct measurement.

Deformation modeling and interpretation of observations (J. Fernández Torres et al.)

Deformation models has been developed and improved for faulting and volcanic loading (see e.g., Charco et al., 2001; Fernández et al., 1999c; Yu et al., 1999; 2002).

The topography effect on the theoretical computations has been study (Folch et al., 2000; Charco et al., 2002) as well as the rheological properties and shape of the intrusion effects (Folch et al., 2000, Fernández et al., 2001). Deformation and gravity changes produced by volcanic loading has been modelled using different theoretical models and the Genethic Algorithm techniques for inversion.

Applying geodetic techniques to monitoring activity involves interpretation using deformation models. Usually gravity change data and displacement data are interpreted separately. Fernández et al. (2001) show, using modeling of deformation and gravity change data in Campi Flegrei, Italy, Mayon Volcano, Philippines, and Long Valley Caldera, California, USA, that this can lead to incorrect interpretations. Also, in the traditional style it can be difficult, if not impossible, to interpret the data coherently or correctly in terms of the characteristics of the intrusion or the deflation derived from the gravity changes with purely elastic models, as in the case of Mayon Volcano, Phillipines. The results obtained show that displacements and gravity changes must be interpreted together whenever possible and that elastic-gravitational models can be a far more appropriate approximation to problems of volcanic load in the crust than the more commonly used purely elastic models. Therefore it is necessary to change the philosophy normally used to interpret geodetic observations, improving the possibility of predicting future eruptions. Also the combination of displacement and gravity changes is found to be especially effective in constraining the possible characteristics of the magmatic intrusion as well as the rheology of the medium surrounding it. Tiampo et al. (2000) model the second inflation period at Long Valley caldera, California using a genetic algorithm technique and high quality geodetic measurements of elevation changes and baseline extensions. They compare two source inversions for both spherical Mogi point sources and the finite prolate ellipsoid of Yang and Davis. A sensitivity analysis for the genetic algorithm is performed based upon synthetic data set inversions on similar sources in order to better constrain the areal location, orientation, and volume of the potential sources.

Volcano monitoring: designing and observation. (J. Fernández Torres et al.)

The geodetic monitoring system in Tenerife, Canary Island, has been theoretically studied by Fernández et al. (1999) and Yu et al. (2000), arriving to the conclusion that it should be changed and extended to cover the full island for volcano monitoring purposes. A clear choice should be a global GPS network. In this context, two research projects were trying to demonstrate the feasibility of using Synthetic Aperture Radar Interferometry, InSAR, for operational decision-making support purposes at a volcanic risk scenario such as the Canary Islands and to define a monitoring system for volcanic hazard in Spain that includes the operative use of InSAR techniques (Carrasco et al., 2000, Fernández et al., 2002, Romero et al., 2002). The results has shown that InSAR is an useful technique for volcano monitoring in Canary Islands. On Tenerife island, two deformations were detected outside the usually observed area, and located in the region were the most recent eruptions on the island have occurred (Fernández et al., 2002). Due to the very poor spatial coverage of the geodetic volcanic monitoring previously performed on the island, that deformation had not been observed before with any other observational technique, and very probably would never be detected without using an observational technique such as InSAR, or any other appropriately distributed to cover the full island. However, it must be stressed that in some areas of the island there is such dense vegetation that InSAR cannot be used to monitor ground displacements, at least in the radar frequency employed by the ERS-1 and ERS-2 satellites used in this study. Therefore previous results made necessary the design and observation of a GPS network in the island for volcano monitoring in combination with other techniques, validation of the deformations detected by InSAR. Rodríguez-Velasco et al. (2002) and Gonzalez-Matesanz et al. (2002) describe the designing, observation methodology, results and interpretation of the GPS surveys conducted in Tenerife. The results has allow to define a new geodetic monitoring system for the full Tenerife island combining InSAR and GPS.

Continuous observation of gravity has been done in Tenerife and Lanzarote islands and the tidal results has been interpreted (Arnoso et al. 2000, 2001).

A design of the geodetic monitoring for the full Canary Island has been done with base on the theoretical and observational results (Fernández and Luzón, 2002).

Cartographic projection (M. J. Sevilla and J. A. Malpica)

Study of some elastic properties of the projections with the Second Order Theory of Chovitz. This lead to give a new projection within the azimuthal ones which yields a minimum for the elastic deformation energy. The application of strain criteria in map projections is proposed by Dermanis et al; since this approach gives cumbersome formula it is used the second order Chovitz theory to facilitate the study. This approach is sufficient for most applications on a small scale. At the same time it is studied the difference between direct formulae and formulae obtained using second order theory.

Geopotential model for the north-east Atlantic (M. J. Sevilla et al.)

A new geopotential model tailored to gravity data in the north-east Atlantic was developed. The new geopotential model (FCUL96B), completed to degree and order 360, has been calculated using a new set of 30’ x 30’ mean free-air gravity anomalies obtained from several ocean gravimetric missions since 1975 to 1990. The calculation of the tailored model was based on the OSU91A coefficient set, that was used as a start model. The comparison of EGM96, OSU91A and FCUL96B, with altimetric data obtained from ERS1 and TOPEX, reveals a better accuracy of the FCUL96B model. In this area EGM96 geopotential model reveals a better fit to the gravity field than OSU91A but not as good as the tailored model FCUL96B. From the results we obtained, we verify that a tailored model can provide a superior reference surface for local and regional solutions, if the gravity data used in the tailoring process was improved in quality or in density.

Satellite altimetry (M.J. Sevilla et al.)

ERS-1 satellite altimetry data corresponding to the second multidisciplinary phase of the satellite, have been used over a zone in the North Atlantic during fifteen months of mission. They have been corrected of all modelled effects. A data validation has been done using criteria related with the observed and average statistical values. Mean arcs are obtained from a year to take out the seasonal effects. After getting them, crossover points between ascending and descending arcs are determined. Residual differences are adjusted by least-squares. Two parameters are obtained for every arc. The mean sea surface obtained with the adjusted residuals is tested over Canary Islands region with a gravimetric geoid.

Satellite altimetry from Geosat (18 months) and ERS-1 (10 months) geodetic missions provide data with a very dense coverage, allowing a very detailed recovery of the gravity field. Stacked data from TOPEX/Poseidon (6 years in a 10 day repeat cycle), ERS-2 (4 years in a 35 day repeat cycle) and Geosat ERM (2 years in a 17 day repeat cycle) are used to define a precise reference frame where the previously mentioned data are adjusted.

The effect of the sea surface topography is reduced by fitting each profile of the sea surface height to the corresponding profile of the EGM96 geoid undulation. A remove-restore procedure is used to obtain residual sea surface heights eliminating the contributions of the low (with the global geopotencial model EGM96 as reference field) and high (the effect of the topography/bathymetry is computed using the RTM correction with the local accurate bathymetric model AZDTM98 and global JGM95E) frequencies to the sea surface heights. A validation procedure is then applied, comparing each value with an estimation obtained using least squares collocation. A cross-over adjustment using bias and tilt parameters is followed by the estimation by least squares collocation of a dense grid of residual geoid undulation using the validated data. Finally an efficient method based on Fast Fourier Transform is used to obtain the residual gravity anomalies by inversion of the mentioned grid. After adding the contributions to the gravity anomalies from the global geopotencial model and from the topography/bathymetry, the result is compared with adjusted gravity data obtained by gravimetric surveys.

High precision bathymety and geoid computation (M. J. Sevilla et al.)

The effect of a new detailed regional terrain model on geoid computation has been studied. A new detailed bathymetric model around Azores Islands has been constructed based on new ocean depth information obtained from echo soundings during ship surveys. These bathymetric data were merged with high precision height data on land producing a new terrain model (AZDTM98) with 1´x1´ resolution on sea and 20´´x20´´ on land. Global digital terrain model JGP95E was compared with AZDTM98 model. Sea and land gravity data covering the area was merged with satellite derived gravity anomalies for geoid computation. Least squares collocation was used for geoid estimation according to the remove-restore technique using EGM96 geopotential model and RTM method. Two geoid solutions were obtained from AZDTM98 and JGP95E models and compared with 134 GPS stations on land and with ERS-1 and ERS-2 altimetric data on sea. From this comparison it was found, on sea, a slight improvement for AZDTM98 model after the removal of the trend surface, reaching the level of 5 cm in the difference between the two models. The new detailed bathymetric/altimetric data did not improve the geoid solution as it was expected.

Gravity and Mean Sea Surface and geoid (M. J. Sevilla et al.)

In the last years, several data sets and gravimetric, bathymetric, mean sea surface models have appeared globally or just for the Mediterranean Sea. Analysing them it is possible to see that there are significant discrepancies between the models provided by different authors or organisations. We present such differences and conclude the most representative choice in our opinion, for the Mediterranean area.

In geodetic and oceanographic studies generally, some reference surfaces are needed. These surfaces must represent as much as possible the gravity .field of the Earth and the height/bathymetry systems. In the last years, several gravimetric, bathymetric, and mean sea surface models have appeared. Analyzing them it is possible to see that there are significant discrepancies between the models provided by different authors or organizations; there are also differences between the models and data obtained by independent measurements. We present the analysis of such differences and determine the most representative choice of models, in our opinion, for the Canary Islands region.

Gravimetric and altimetric data are used to assess an estimation of the sea surface topography in the Western Mediterranean Sea. This is a complex area from different points of view, due to the presence of several islands, coastal lines, shallow waters and a peculiar hydrologic equilibrium due to its proximity to the Atlantic water exchange area. Firstly, a gravimetric geoid was computed using the least-squares collocation (LSC) procedure with the classical remove-restore technique. We also present a local mean sea surface generated from repeat ERS-1 altimeter data fitted to TOPEX. We chose this satellite because it offers a better spatial resolution than the TOPEX data. The time span used in the computations is one year. This is a useful interval for averaging out the regular seasonal variations, which are very large in this area. We present the comparisons between the gravimetric geoidal heights and the adjusted sea surface. This is a way to obtain a rough estimation of the sea surface topography (SST) since we also include the errors in the two surfaces and other oceanic signals. The differences obtained are physically reasonable with a mean of 17 cm and standard deviation (s.d.) of 39 cm. A significant similarity is observed between the features reproduced by these differences and the bathymetry in the area, suggesting some sort of correlation between both magnitudes for the studied region. If we accept such correlation, the SST may be described as a function of depth. This procedure lets us filter out the short wavelength part of the geoid from the first SST estimation.

A mean sea surface model is used as the frame of reference in processing altimeter data. This work focuses on ascertaining the extent to which results depend on the different mean sea surface models used. In particular, we have analyzed the results from the OSU95MSS and the CLS SHOMv.98.2 models in an area in the North Atlantic Ocean comprising the Canary and Azores Islands. Special attention has been paid to data editing and several criteria were proposed. The amount of detected data is quite small because we used a well corrected data set. However, it was enough to show important relations between the applied criteria and the kind of area. Therefore we analyzed the best way to apply these criteria according to the areas where the points have been found. Singular areas related to several factors have been detected by all the suggested criteria. In particular, rough sea bottom features, dynamic circulation, and amphidromic points of the tidal waves, among others. As a result of this analysis, we have not considered it appropriate to remove all the detected points. Two time-averaged and corrected mean sea surfaces were determined in the test area.

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3. INSTITUTE CARTOGRAPHIC OF CATALONIA (BARCELONA)

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1. SPGIC: Sistema de Posicionament Geodèsic Integrat de Catalunya

Since 1991, the *Institut Cartogràfic de Catalunya* (ICC) has been working on the SPGIC project (Integrated Geodetic Positioning System of Catalonia), based on sparse geodetic networks, the knowledge of the geoid and GPS. SPGIC may be defined as a set of geodetic permanent stations, networks, procedures, regulation data, communications, software, hardware and technical advice for the purpose of high-precision local positioning in Catalonia.

1.1 XU: Xarxa Utilitària de Catalunya

The objective of the XU is to have a modern and accessible geodetic network. Modern because XU is a three-dimensional network, where horizontal and vertical components are computed at the same time. Accessible because the distribution of its points adapts to user necessities and technology. In order to know the description, location, coordinates and information associated with each one of the XU vertices, for each point a file with all the information is generated. These files can be consulted and printed free of charge through Internet (http://www.icc.es/ressenyes/homeang.html).

Until the end of 2002, XU has observed 2138 points with GPS technology. In the next years the ICC try to finalize the implantation of the XU with about 2000 additional points, at the rate of about 250 points per year. The density of the XU depends on the difficulty of ROI access and on the dynamics of the territory.

1.2 XdA: Xarxa d'Anivellació

In a high dynamical territory, like Catalonia, the conservation of the leveling network can become a difficult task. In order to densify the NAP (*Nivelación de Alta Precisión)* network from the *Instituto Geográfico Nacional* (IGN) the ICC is leveling since 1998 the Xda network. Other objectives of the XdA are the aim to obtain a more homogenous coverage and to improve the conservation of the leveling points in Catalonia. The permanent GPS stations (CATNET) are also being leveled as part of the XdA project. At the end of the 2002, 456 km have been measured, continuing its observation at the rate of 100 km annual. XdA assures a precision 1mm by square root of level km.

Since a part of the leveling signals are located in optimal sites for the GPS measures, the XdA facilitates the precise determination of geoid profiles. These profiles are useful for the evaluation of the precision of the geoid and for its later improvements.

1.3 Tidal gauge stations

Since 1990, the ICC has been storing data from the tidal gauge station l'Estartit and has been collaborating with other institutions in Spain.

1.4 GPS permanent stations

One of the kernels of SPGIC project is the network of GNSS permanent stations that the ICC has implanted on Catalonia (CATNET). The network was conceived mainly to offer a public service of GPS data. Its main client is the own ICC, for the necessities of kinematic positioning of its airplanes. The network was designed from an initial triangle (corresponding to the three ends of the Catalan territory) and has been densifyed progressively towards the interior. Throughout 1999, the first phase of this densification was completed with a network of 8 stations (5 of them members of the EUREF Permanent Network, EPN). From year 2000 the second phase of this densification is under deployment. Ending with a total of 14 stations in 2004. The coverage provided by a set of 14 stations will allow implementing systems of RTK positioning in real time in a robust form, since the mean distance between stations will be of 70 km.

We can distinguish two types of stations: geodynamics, in which the point is materialized with a structure of great robustness anchored in the subsoil and that is going to allow to us to use its data for studies of cortical deformations; and non-geodynamic, with one structure that guarantees the stability of the antenna in the long term although not at the mm level. All the stations implemented during the first phase belong to the geodynamic type whereas in the second phase they are going away combining geodynamic stations with non-geodynamic stations.

By reasons for redundancy the data can be downloaded to ICC by two different ways via modem or via satellite using VSAT (Very Small Aperture Terminal) network. Since 1999, VSAT technology is considered as the main telecommunications system to the GPS stations, covering at the present time 7 of the total of 10 stations. This implantation is made jointly with the Unit of Geology that has implanted it in its new seismic network.

1.4.1. GeoFons

The GeoFons service, initiated in 1995 and at the moment through Internet, have been extended and improved, offering now the following products:

- Observations of CATNET network. RINEX standard format has been adopted for all GPS files, as a standard product.
- Geoid, datum transformation parameters, XU coordinates, etc.
- Reviews of the XU points.
- Software of free distribution created by ICC.

Daily, the files of GNSS data of stations AVEL, BELL, CREU, GARR, EBRE, ESCO, LLIV, MNTC and PLAN are available in the network, as much in form of hour-files at a rate of 15 seconds, like in daily-files at a rate of 30 seconds. In addition, VSAT system offers to the users hour-files at 1-second rate for AVEL, BELL, CREU, EBRE, GARR, LLIV and PLAN stations after few minutes to complete the hour in course. This capacity will be extended to the rest of stations according to these are incorporating VSAT system. The availability online of the hour-files is of 30 days, although also service is offered off-line under order to geofons@icc.es. Access to the GeoFons service is free of charge through anonymous FTP (ftp.icc.es). More information can be found in http://www.icc.es.

1.4.2. RASANT

Since 1995 the ICC is offering the RASANT service consisting in the transmission of RTCM SC-104 code corrections via Radio Data System (RDS). Its operative phase initiated at the beginning of 2001 with the installation of the Integrity Monitor System, according to standards RSIM. This system allows a continuous monitoring of the state of the broadcasting and the quality of the transmitted corrections.

1.4.3. CATNET-IP

The use of Internet and the present facilities for movable devices to access Internet, as well as their capacity to transmit data continuously, make this way of data transfer very suitable to offer several differential positioning services. With this goal and leaded by the BKG (*Bundesamt für Kartographie und Geodäsie*) within the EUREF-IP project, the ICC has started a test phase of the service CATNET-IP, based on a station installed in the ICC.

The service works under the concept of client-servant. The servant gathers the data of a GPS receiver and makes available for the clients, via TCP/UDP ports, the generated data. The IANA (Internet Assigned Numbers Authority) has reserved ports 2001 and 2003 for the transmission of differential GPS data by Internet. Thus the client applications, in fixed platforms or movable, select a servant through its connection to Internet and connect its client application. For more information about this project and for unloading sample software, one can visit the following Internet site, http://igs.ifag.de/euref_realtime.htm

1.4.4. CATPOS

The ICC is developing a public positioning service, free of charge, CATPOS, which provides GPS users of coordinates at centimetre level (up to 10 cm depending on the quality of the data) from the network of permanent stations CATNET.

It offers a positioning system based on double frequency static GPS data, in RINEX format and using Internet technology. After making a GPS observation in a point, the user must fill in a questionnaire, which sends his observation file to the ICC. Then an automatic process is activated based on the Bernese Processing Engine (BPE) of the Bernese Software Package v.4.2. Each file will be processed with respect three CATNET stations. The selected stations are chosen considering the distance, number of observations, operatively, etc. The position associated to the data will be given back to the user via electronic mail in few minutes.

1.5. GeoCat: Geoide de Catalunya

Geoid determination is still one of the main activities of the geodetic research. Since the determination of the geoid of Catalonia, UB91, in 1991, the situation has been improved sensibly:

- There are new global gravity field models (EGM96, EGG97, GPM98), which have improved considerably the OSU89 model used in UB91 determination.
- Combined GPS/levelling observations in XU-XdA points.
- New DTM determination of Catalonia.
- Points with observed deflections of the vertical.

It has been detected and corrected an absolute offset of 80 cm observed in the UB91 geoid.
Also in some projects, several areas with great gradient disturbances have been detected.

There are plans for a new determination of a precise Catalan geoid by using GRAVSOFT software. GRAVSOFT is a FORTRAN package that allows the determination of the gravity field, specially the determination of local geoid models using the well-known remove-restore technique.

The ICC has collaborated in some projects about sea level measures based on GPS buoys:

- CATALA: absolute calibration of the altimeter Topex Poseidon. In this project, 2 GPS buoys have designed and built. Each buoy consists of a floating system to lodge a choke ring antenna for the precise study of the sea surface. The ICC has participated in the GPS observation campaign in the zone of Llafranc. It has made the assembly and the control of a reference station in the zone. It has built and observed with GPS a leveling benchmark in the port of Llafranc in order to equip with precise height a tide gauge located in this port.

- CRAC: development of a system of geocentric measures of the sea level (FEDER 2FD97-0588). The ICC has participated in two observation campaigns with the GPS buoys defined in the CATALA project.

2. High precision positioning

Within the frame of the PotSis (Potencialitat Sísmica del Pirineu Oriental) project for measuring crustal movements in the eastern Pyrenees the, PotSis'99 campaign has been carried out. The campaign was done from 28 June 2000 until 2 July 2000 with 11 receivers GPS (3 Trimble 4000 SSI, 1 Trimble 4000 SSE and 7 AshTech Z-xii3), antennas choke Ring and permanent station CATNET of Llivia (LLIV). The PotSis point in Llivia has been connected with the CATNET station LLIV, so continuous GPS data are obtained for this study. The Bernese software package v.3.5 has been used order to calculate the GPS baselines using final IGS precise orbits and data from the nearest EUREF permanent stations. The resulting network has been adjusted using GeoTeX/ACX and a precision of 3,5 in planimetry and 5 mm in altimetry have been obtained for the 24 points of the PotSis network.

3. GEOVAN

Land Based - Mobile Mapping Systems (LB-MMS) is a technique for compiling cartographic information from a mobile vehicle. With the objective to develop its own LB-MMS the ICC has developed the project GEOVAN. GEOVAN is based on the orientation and positioning subsystems and allows a flexible integration of different kinds of sensors (digital cameras, lasers…). The system is equipped with a structure where the sensors are rigidly attached, so it is possible to transfer the orientation computed by the GPS/IMU to the Earth observation sensors. Initially GEOVAN integrates two digital cameras in order to form oriented stereoscopic models.

5. GeoTeX: Geodèsia, Teledetecció i Xarxes

The GeoTeX system is a general geodetic and photogrammetric point determination system, which is able to deal with any type of geometric functional model.

The automatic error detection during the computation allows, together with the dynamic implementation and memory allocation of the new version of the AdIL format, ACX to be a robust and operative system for any kind of project. During this period, it has been continued the development and implementation of new mathematical models and new tools to transform data.

6. Public service

The ICC is collaborating with l'Escola d'Enginyeria Tècnica Topogràfica de la Universitat Politècnica de Barcelona (UPC) and Departament d' Enginyeria de Geodèsia, Cartografia i Fotogrametria, Universitat Politècnica de Valencia on several student diploma projects.

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1. REFERENCE SYSTEMS

1.1 REGENTE

Aiming the set of an unified European cartography, it is indispensable the coordinate conversion of National Geodetic Reference Frames to the ETRF89 Frame. Such a determination requires the knowledge of coordinates in both systems in a very high number of stations uniformly distributed, should this number be higher if the irregularities in the local Frame increase.

In the case of Iberian Peninsula and archipelagos, the IGN decide to fix the problem by REGENTE Project (Spatial technique National Geodetic Network), consisting of setting up a dense GPS high precision network with coincident stations to ROI (Third Order Geodetic Network) and some benchmarks of High Precision Levelling Network. The mean density was fixed to one station per MTN sheet (National Surveying Map) scale 1:50,000, that is, one station per 300 km^2.

REGENTE will be perfectly linked to the ETRF89 reference network, thus IBERIA95 and BALEAR98 which stations are REGENTE points as well. REGENTE Canarias (Canary Islands) was leaned, as reference station, on Maspalomas (VLBI and IGS station).

Objetives
With REGENTE Project the following objectives are reached:

- Implementation, observation and co-ordinate determination, for entire Spain, of a three-dimensional basic class C network, with an absolute precision better or equal than 5 cm.
- Obtainment of precise transformation parameters between reference system of National Geodetic Network, ED50, and that of REGENTE, ETRF89.
- To ease valid data to debug Spanish geoid of centimetre precision. REGENTE project is supported with relative Lacoste-Romberg gravimetric observations in every point.
- To ease support to the high number of GPS technique users, so that any national point could be inside a maximum circle of 15 km. with centre in a REGENTE station.

REGENTE points have to fulfil the following requirements:

- Belong to the National Geodetic Network, or VLBI or SLR.
- Common features to a GPS station: easy vehicle access, open horizon above 10º, enough distance from elements, which might cause multipath or interferences.
- As REGENTE is a three-dimensional network with observed ellipsoidal heights referred to GRS80 and should perfectly be linked to National Geodetic Network ED50, which heights are referred to sea level, it has been established that more than 10 percent of points should have orthometric height, with sub-centimetre precision, through the link to the High Precision Levelling Network, NAP.
- Whenever the requirements of a GPS station are fulfilled, the Laplace points will be included in REGENTE and the second order astronomical stations.
- Each point of IBERIA95 and its extend BALEAR98, belong to REGENTE.
- To serve as a reference frame for local networks used for geodynamic.

In the same way, 12 points have been included in Canary Islands REGENTE net. Its fundamental point is the VLBI station of Maspalomas, in Gran Canaria.

Realization
The mark and observation tasks which begun in 1994 reached two thirds of the project in 1998, and kept on through the period concerning this report till their end in 2001.

Definite structure
REGENTE consists of around 1078 stations in the Iberian Peninsula and Balearic Islands, one per MTN sheet (National Surveying Map) scale 1:50,000, which implies a mean distance of 20 to 25 km between stations. In the Canary Islands, REGENTE Canarias, REGCAN95, consists of 72 stations delivered in seven islands with a maximum of 21 in Tenerife, and being 5 the minimum in every minor islands of El Hierro and La Gomera.

1.1 GPS Reference Station Network (ERGPS)

Introduction.
Since its in 1991 the International GPS Service (IGS), more than 220 permanent stations operate continuously with double frequency GPS receivers with the objectives: to better, extend and define the International Reference Frame (ITRF); study of terrestrial Geodynamics; determination earth rotation variations and pole coordinates; processing and distribution of precise orbits.

It was the IAG sub-commission for Europe, EUREF, which decided the set and control of the permanent European GPS Network, by forming a densification called EUREF Permanent Network (EPN).

The Spanish network, ERGPS.

Since March 1998 when the National Geographic Institute begun the installation of permanent stations on national territory, 16 ERGPS form the current network, which is fully operative and ten of them serve data to IGS and EUREF for definition of World and European Frames, respectively.

The link of Yebes permanent station (YEBE) to the telescope by high precision geodetic observations and its integration in IGS makes possible the transference from VLBI observations to the network, being its kernel of IGN analysis.

The ERGPS already installed are located in:

- ALAC - Tide-Gauge of Alicante (IGN).
- ACOR - Tide-Gauge of La Coruña (IGN).
- YEBE - Observatorio Astronómico de Yebes (IGN).
- ALME - Observatorio Geofísico de Almería (IGN).
- VALE - Universidad de Valencia.
- MALL - Instituto Español de Oceanografía de Mallorca.
- MALA - Observatorio Geofísico de Málaga (IGN).
- CANT - Escuela de Ingenieros de Caminos, Canales y Puertos (Univ. Cantabria).
- SONS - Observatorio Sismológico de Sonseca (IGN).
- CACE - Universidad de Extremadura en Cáceres.
- RIOJ - Observatorio Geofísico de Logroño (IGN).
- LPAL - Observatorio Astronómico Roque de los Muchachos (Inst. Astrofísico de Canarias).
- CEUT - Autoridad Portuaria de Ceuta.
- HUEL - Universidad de Huelva.
- VIGO - Instituto Español de Oceanografía de Vigo.
- ALBA - Universidad de Albacete.

The following table shows the data availability dates, the belonging network to EUREF or IGS and the hourly transfer data in "near real time" (nrt < 10 minutes).

ERGPS	Datos	EUREF	IGS	Nrt
ALAC	04 / 98	X		
ACOR	01 / 99	X		
YEBE	05 / 99	X	X	X
ALME	12 / 99	X		
VALE	12 / 99	X		X
CANT	03 / 00	X		X
MALA	03 / 00			
MALL	05 / 00	X		X
SONS	12 / 00			
CACE	12 / 00	X		X
RIOJ	04 / 01			
LPAL	05 / 01	X		
CEUT	07 / 01	X		
VIGO	09 / 01			
HUEL	12 / 01			
ALBA	09 / 02			

Table 1 – ERGPS Network.

ERGPS Objetives.

- Obtainment of very precise coordinates and velocity field in all points of the network.
- Contribution to new definition of Global Reference Systems (ITRFxx).
- To belong to European Network of permanent stations (European Reference Frame).
- To use raw continuous data for Geodynamical, Tropospheric, Ionospheric studies.
- To provide GPS users, publicly, data for geodetic, cartographic, surveying and positioning works in general.

Data flow.

Data generated from ERGPS are daily recorded and sent automatically to IGN Central facilities in Madrid (Euref Local DATA Centre) by INTERNET network or phone lines. Data transmission is carried out by ADSL line for stations which had only pone line.

IGN processes raw data, checks quality and arranges the next sub products for the scientific community and itself, incide the analysis step.

Data are sent automatically by internet to EUREF Regional Data Centre in Frankfurt (Germany), and arranged in a public access IGN data server.

Acknowledgment.

We acknowledge collaboration to all public institutions which collaborate in installing and maintain the National Permanent Station Network.

1.1 GPS permanent network processing by IGN: Analysis Centre of EUREF

Introduction.

Actually, 16 stations form the National GPS Station Network (ERGPS) of IGN. Most of them are integrated in EUREF or IGS, and keep de organisation of EPN, that could be sum up in:

- *Local Data Centres (LDC).* They receive the data of all stations of a local network and distribute them to the users.

- *Regional Data Centres (RDC).* They save all EUREF stations data, and even IGS.

- *Local Analysis Centres (LAC).* They process a subnetwork of EUREF stations. Now there are 16 LAC´s in Europe.

- *Regional Analysis Centre (RAC).* Coordinates the global processing, combining and linking the different sub networks of LAC, offering weekly results in SINEX format to be sent to IGS. Nowadays this task is carried by Bundesamt fur Kartographie und Geodaesie (Germany).

Together with the station data management, the main EPN product is the weekly estimate of station coordinates. This is the so called "EUREF combined solution", based on combination of solutions given by the LACs. They process their sub networks following a specific rules. The weekly combined solution is formed after removal of constraint ments made by LACs, adjusting the global solution to the International Terrestrial Reference Frame (ITRF) fixing a selected station set, which are updated monthly from ITRF velocity fields.

Thus, each EPN station is processed by at least three LACs. These solutions, both LACs and weekly combined solution, are available through anonymous ftp:// igs.ifag.de/pub/EUREF/products/(GPS week) o ftp://epncb.oma.be/pub/product/combin

IGN, Local Analysis Centre of EUREF.

Since the first web of September (GPS WEEK 1130) and after the tests made when introducing our solution into the final combined European solution with satisfactory results, the IGN geodetic department has became an EUREF Analysis Centre, processing an Iberian network with a total of 23 permanent stations. The three letter acronym used is IGE.

Processing is done by Bernese Proccessing Engine BPE 4.2, as an automatic procedure. Weekly solutions are reported in SINEX format (Solution INdependent EXchange format), together with a weekly SUMMARY of results and seven troposphere parameter files (one per week day) corresponding to a special project of estimation of troposphere parameters (zenith path delays) of EUREF.

The processing strategy carried out by IGN fulfils the last recommendations of LAC´s workshop which took place in Warsaw, to which all LAC´s since GPS web 1130 (2nd September 2001), date of official joining of IGE as Analysis Centre of EUREF.

Processing strategy.
The Bernese Processing Engine (BPE) module allows, through chaining scripts, automatically achieve fulfil in an optimal way all processing, which, step by step, would be tedious. Almost all LACs used Bernese software for their sub network analysis. Platforms where BPE is run in IGE are Unix and Linux.

The main processing rules, following EUREF general specifications are:

Pre-processing: phase by using triple differences in baseline mode. Most of cases the cycle slips are simultaneously fixed by different linear combinations of L1 and L2. If a cycle slip are not fixed, the bad data are removed and new ambiguities are fixed.

Basic observable: of course, phase carrier. Code is only used to synchronize receiver clocks.

Elevation mask : 10 degrees.

Data interval to fix ambiguities : 60 s.

Data interval of final processing: 180 s.

Modelled observable: double differences and ionosphere free linear combination.

Phase antenna centre calibrations: corrections to phase centre dependent of elevation for different types of antennas, according to IGS calibrations.

Troposphere: a priori Saastamoinen model and estimation of ZPDs (zenit path delays) with 1 hour interval for each station by Dry-Neill function. Besides this generates troposphere files already quoted for a special project of troposphere parameter estimation.

Ionosphere: not modelled in final solution, ionosphere removed bye forming free ionosphere combination with L1-L2.

Orbits and ERP´s (Earth Rotation Parameters) and final IGS precise orbits.

Other parameters: planet ephemerides DE200, JGM3 potential model and GOT99 ocean loading and tide model (last recommended by IGS).

Removal rule: none during parameter estimation. Outliers are marked when pre-processing.

Constraints: only YEBE (0,1 mm), network kernel, weekly updated coordinates with ITRF2000 velocities, coming from VLBI. Radiotelescope vector VLBI-GPS perfectly determined.

Troposphere: hourly estimation of ZPD´s for every station.

Ionosphere: not estimated.

Ambiguities: QIF strategy (Quasy Ionosphere Free) for ambiguity resolution for every baseline. These fixed ambiguities are introduced into the final solution.

Satellite clocks: drifts are not estimated, but removed by forming double differences.

Receiver clocks: drifts estimated during pre-processing using code measurements.

2. MANTEINANCE OF GEODETIC NETWORKS

Maintenance of the third order geodetic network (ROI)

During 2000, 2001 and 2002 the ROI maintenance that concerns to disappeared points due to different causes (public constructions, urbanizations and so on) has been carried out, where a new mark must be placed, the observation and compute the new coordinates.

- In 2000 the network was densified in Segovia province with 33 new station marks.
- In 2001 17 station marks were repaired in Ávila province.
- In 2002 46 station marks were repaired Cáceres province.

3. A PUBLIC SERVICE. Geodetic Data Server (SERDAG)

Origin of project
From the following elements:
- *Geodetic Data:* coming from field observations (old or new), with a new structure in digital format and Data Base storage.
- *IGN or external Users* (technicians, enterprises and state national and international Institutions) who need this data for their work.
- *Technological Advance:* which serve Observations and allow a new way to deliver data.

IGN Geodetic Department, is forced to develop a tool to give service that users demand:
The Geodetic Data Server would like to put available to any user the records included in Geodetic Department data bases through searchers via Internet with an easy, quick and friendly access.

Data Bases: developement
From ROI (Third Order Geodetic Network), begun in 1994 the development of the structure of future Data Bases under Microsoft Access®.
Development Phases:
- Best structure study (tables, fields, data...)
- Design of and relationships between tables, queries, display forms and printed reports only for internal works.
- Base creation with study and design steps.
- Available data loading (old and new observations) and links to similar elements to those data (photographs, drafts...)

This last step is being execute continuously and updates Data Bases with new observation records.

Data Bases: types
From this structure, the following Data Bases have been elaborated:
- **Territorial information**. Data coming from "Consejo Superior Geográfico" needed for territorial record linking.
- **Geodetic Network (ROI)**. ED50 and WGS84 coordinates, angle observations, station sheet, photo, sketch... of geodetic points.
- **Gravimetric Network**. Geographic and Gravimetric data, reseñas, topographic correction ...
- **New Levelling Network**. Data from nails that form the levelling lines and branches. It includes Bases from *CANARIAS* and *INTERREG-II*. Now the Spanish Network is being reobservation phase.
- **Tide-Gauge Network**. *Being developed*. **Special works**. *AENA* and *TUNEL PIRINEOS.*

Data Bases: GPS Permanent Stations
They are special data that are not organized in a Data Base. They are stored in files structured by: Station coming from (out of 20 that form the network); date and hour interval of observation (full day or hour window); Time Interval (in seconds) between observations (every 5 or 30 s); and Type of values contained as Observations or Navigation Data.

SERDAG Tool
Application physically placed in a Server and consists of several Web pages and programs that, through inquires sent by a customer via Internet, looks for geodetic data in copies of the data bases and delivers them in order in a specific way.
It is fully complete with:
- A set of information pages about features and record type of Data Bases.
- Utility tools for data management.

The server is structured in the following components:
- *Geodetic Data Bases:* Copy from originals and only read property.
- *Permanent GPS station Data Files*: Records formed daily with raw data delivered by the stations.
- *Applications*: Programs and utilities developed to ease user´s work with data provided. They are specific of each base and others are shared.
- *Customer Data Bases:* For user registration that ask for data and control of receivement.

Data Server: It is the main task made by th Server. Basically consists of:
- *Program*: Program code developed in VisualScript. It is in charge to deal with Data Bases and their formulars arrived from customers and data sent as a result of a search.
- *Web pages*: HTML and DHTML code. It is the element for the Program to connect to customer.

Component Organization
In order to implement the Main Page, different components are delivered in two levels:

General Information. Explain every Data Base, its records, utility to be given and linked aplications.

Searchers. Specific for each Data Base. Facilitate access to its records through múltiple options.

SERDAG. It gives access to main page which reports briefly about Data Bases.
- **General Information.** Contains all general information level.
- **Geodesy in the World.** Special Section that includes addresses and links in Internet where to find more geodetic data.
- **Data searchers:** Permanent GPS Stations; Geodetic Network; Levelling; Network; Tide-Gauge Stations; Gravimetric Network

1. SPECIAL WORKS

1.1. Coordinate determination in WGS84 system of "VILSPA1" antenna and calibration tower in spatial facilities of Villafranca Del Castillo (ESA)

By request of European Spatial Agency was done october 1999 with:

Objetives
The aim of this work was to obtain WGS84 system coordinates to 15 m antenna named VILSPA1 and two calibrating antennas, placed in a metallic tower of about 40 m height. The following procedure:

Realization
First a GPS six point network was observed, with double Trimble 4000 SSE frequency receivers. These points are:

"**REF**1", "**REF2**" and "**REF3**", around VILSPA1 antenna;
"**VILA2**", near SATAN antenna
"**VILA3BIS**", in station main building terrace. New point due to "VILA3" disappearance.
"**Doppler Este**", named 5582 in spanish national GPS REGENTE network.

Observation time varied between 2h 08m the lowest and 3h 04m the highest, with a 15 s interval measurement and a elevation mask of 15º.

Secondly from three references were got the eight points (coordinates) of the structure of the antenna., through bisection with Wild T2 theodolites and distance measurements with Wild Distomat DI-3000, to determine the geometric centre.

In third place, from VILA2 and VILA3BIS, two antennas were radiated and the pointing triangle placed in calibration tower by a Wild T2 and Will Distomat DI-3000 distance meter.

Processing
Vector processing of GPs network was done with GPSurvey Trimble Navigation software, using 5582 point as fiducially, already quoted as REGENTE network point, which is defined in WGS84 system.

Afterwards an adjustment of those resultant vectors was made with Geolab sofware, obtaining finally the WGS84 ellipsoidal coordinates of the rest 5 points.

From the three point coordinates called REF1, REF2, and REF3, a least squares adjustment of the angle and distance observations for the determination of the eight structure points of VILSPA1 was made. A least squares adjustment of the three calibration tower points was also made.
These last ones were also prcessed with Geolab software.

1.1. High precision levelling and GPS tasks for National Airports And Aerial Navigation (AENA).

The Geodetic Department of Instituto Geografico Nacional carried out in 1999 a GPS campaign for transfer geometric orthometric height to **twenty four** airports in the Iberia Peninsula, other **three** airports in the Balearic Islands, and one in the city of Melilla. In Canary Islands airports a high precision levelling network (NAP) was done, due to the small distance between AENA signal chosen in each airport and the corresponding NAP line of the isle.

Objetive
To give orthometric height with a better precision than 0.10 m, to the levelling networks built by AENA in their 36 airports.

Methodology
With support on REGENTE and in two benchmarks of High Precision Levelling Network of IGN (NAP) closer to the airport, the observed network was completed with two signals of the levelling network established by AENA inside each airport. This methodology was applied to 24 peninsular airports, 3 in the Balearic Isles and 1 in the city of Melilla.

Processing
UIT the specific compensation in each airport within the frame of REGENTE, ellipsoidal coordinates (WGS84) to AENA point network are given, the knowledge of orthometric and ellipsoidal heights in the close levelling marks (NAP), allows to determine an mean geoid undulation value above WGS84 ellipsoid, valid for any point at the airport not lower than a 0.05 m precision. In the isles, given the actual uncertainty in th precise determination of mean sea level (as a consequence of the limited observation time of tide gauges installed, or lack of them), the uncertainty was increased to 0.10 m.
The precise geoid knowledge in every airport facilitates greatly the use of GPS observations in them, allowing ellipsoidal height conversion to orthometric (and vice versa) within the assigned precision to the geoid undulation.

3.3 Vertical deviation determination in millimetrical radioastronomic observatory of Pico Veleta

In July 2000 the necessary tasks to determine vertical deviation, the angle between ellipsoid normal and geoid normal at the same point placed for this purpose in Pico Veleta, were carried out.

In order to obtain the vertical deviation in a point the suitable relationships between astronomical coordinates Φ, Λ, H and geodetic coordinates φ, λ, h referred to a certain ellipsoid.

Astronomical and geodetic coordinates differ in vertical deviation (ξ and η components) and orthometric and ellipsoidal heights, in an *N* value known as geoid undulation.
Astronomical coordinates must be referred to an inertial reference system, thus in XXIIIth IAU General Assembly, which took place in august 1997 in Kyoto, it was decided to adopt a new conventional celestial reference system, which axes were defined by IERS Celestial Reference System (International Earth Rotation Service), and its materialization would be the ICRF (International Celestial Reference Frame) epoch J2000.0 which mean ecuatorial coordinates are determined by VLBI (Very Long Base Interferometry) observations of extragalactic radio-sources.

ICRS pole is consistent to FK5, with an uncertainty of FK5 position related to mean J2000.0 pole is around 50 mas. Right ascension origin of FK5 has a displacement from ICRS of –22.9 mas.

Similarly, geodetic coordinates have a global reference system, ITRS (International Reference Terrestrial System) of IERS and which materialization is ITRF (International Terrestrial Reference Frame) with GRS80 associated ellipsoid, which coincides for our sake with WGS84 GPS system ellipsoid.

Thus the procedure for astronomical and geodetic coordinates is:

Methodology
A pillar near the observatory was build, so that geodetic and astronomical observations were made.

Geodetic observations
In order to obtain geodetic coordinates a double frequency Trimble SSi receiver was continuously used recording from 12th July till 14th July in astronomic pillar.
Simultaneously a double frequency receiver Trimble SE for geodetic point “Cañadillas” (belongs to REGENTE network) and ROI geodetic point “Veleta”.
Finally the GPS Reference Stations of IGN in Malaga and Almeria were used, which continuously record generating 24 hours data.

Astronomical observations
To obtain astronomical coordinates a Wild T4 theodolite were used from 14th to 18th July and FK5 star were observed. To determine the longitude with Mayer method were used eleven sets with a minimum of eight stars each observed set, amounting a total of 90 stars. To determine the latitude with Sterneck Method was used. a total of 127 stars were observed, delivered in three sets.

Processing Geodetic Observations
GPS network vector processing was executed with Trimble GPSurvey software, using control points as Malaga, Almeria and REGENTE point “Cañadillas”, already quoted as belonging to REGENTE point. All of them are defined in WGS84.
After that, an adjustment of those values with Geolab sofware was done, obtaining as result the WGS84 ellipsoidal coordinates for IRAM Observatory point and the ROI Veleta point.

Astronomical Observations

Processing of astronomical observations for longitude and latitude determination, has been executed with updated to J2000.0 Mayer and Sterneck software by Prof. Miguel Sevilla from UCM University.

4.4. Canary islands geoid determination through GPS and levelling.

Introduction.
GPS wide use by geodetic and surveying community for coordinate determination in engineering and surveying applications outstands the importance of surface geoid knowledge. Thus for example, the difference between ellipsoidal (h) GPS WGS84 obtained height and orthometric height could reach 10 cm/km in the Canary Islands, which indicates not validity in obtaining GPS or orthometric height differences without a knowledge of a reliable geoid. Although the geoid is a physical surface, its practical use with GPS has a geometric meaning (h=H+N).
Besides, in cartographic, surveying civil engeneering or even navigation applications, the ellipsoidal altitude do not has a real meaning, so WGS84 system substitution instead of traditional reference systems should live with geoid referred height.

Precision levelling and GPS in Canary Islands.

In 1997 the Geodetic Department of IGN, through a subscribed treaty between CNIG and "Consejería de Política Territorial del Gobierno de Canarias", dealt with the task of constructing and observing the high precision height networks in all islands of the archipelago. In autumn of that year begun observation in eastern isles (Gran Canaria, Fuerteventura and Lanzarote), with a total of 575 kilometres double high precision levelling. In 2000, observation was completed in western islands (Tenerife, La Gomera, El Hierro and La Palma) with another 600 kilometres.

At the same time, through GPS observations with double frequency receivers and rapid static method WGS84 coordinates to almost all height network points were given, with 2 cm RMS error in vectors, and gravity values.

Geoid determination.

The practical geoid undulation knowledge combining precise levelling and GPS observations does not present any problem, because N=h-H, obtaining a RMS error in N determination, $s^2_N=s^2_H+s^2_h=\pm$ 0,03 meters, which shows validity of the method.

In this way levelling points and geodetic points were processed (REGCAN, ROI and 4º order) the geoid undulation with respect to WGS84 reference ellipsoid, in the three eastern isles, establishing a quality control by kriging croscorrelation, to reject possible mistaken data or with not enough precision.

Extension to all undulation values to all surface was build with a regular net of points covering the whole extension of each isle, of 500x500 meters, extrapolating the undulation value with an mathematical way.

Model obtainment.

Kriging has been the used estimator. Tha samples are weighted and a law to each sample is attributed; these weights are calculated to get a minimum in estimation variance, considering geometrical features of the sample, in that refers to shape, dimensions and relative data positioning, those estimated and those tha could be estimated.

To minimize the estimate variance and the application equations of kriging to a sample, it is necessary to know before its change and its defining equation and shape. This function is called experimental variogram, which is adjusted to a mathematical model to introduce into the equations afterwards. The present work every isle experimental variogram is determined in eight plane directions, 45º.

Once calculated and drawn, experimental variograms in eight directions, a test to prove isotropy must be done, that is, all are statistical images of the same underlying variogram (shape and parameter values). Thus, all can be then sum up in a mean variogram and to fit to a mathematical curve (spherical, power, gaussian, etc) which will be introduced in the kriging equations. Then geoid models have been determined by different way for the three islands, called GPSNIV.

Combination with gravimetric geoid

This method has a weaker precision when extrapolated values are far away from points of height network. For this reason, a second model using shape of a gravimetric geoid was used, combining it with undulation values obtained from height networks. CANGEO97 was the chosen model (M. J. Sevilla), made by "Facultad de Ciencias Matemáticas UCM" with data bases from IGN, GEOMED, Bureau Gravimetrique International and DMA, and a proven quality. Eventually, a scaling was done, extrapolating differences encountered in levelling networks. Process can be summed up into the following steps:

- Construction of a regular point net (500x500 meters).
- N_{CANGEO} values were given to points of regular net and to height network points.
- Obtainment of $N_{OBSERVED}$-N_{CANGEO} difference in the network.
- Extrapolation by kriging of point differences of regular net.
- Obtainment in regular net of corrected undulation values (N_{CANGEO} + dif_{KRIG}).

Advantages for this method are evident as geoid tendency in far regions from height network and while extrapolating through kriging the differences encountered and not N value, so the variance of kriging is lower (40 times).

Finally, practical exploitation of final model (CANGEO97 scaled) is carried out by a program which makes a bicubic interpolation from introduced coordinates over 16 points of net and gives N and vertical deviation components.

Conclusion.

The exposed method is an excellent procedure to obtain the geoid with better than 0.03 metros, useful to develop GPS all tasks with orthometric altitudes needed.

To get the high precision levelling observation of height networks in western islands of archipelago has permitted geoid obtainment in the rest of isles, giving a save frame to determine orthometric heights with GPS and validating a procedure to extend it in future to the rest of Spanish territory in REDNAP.

1.1. Coordinate determination in radiobeacons from "Puertos Del Estado"

State Institution "Puertos del Estado" wanted to increase the radioeletric aids to navigation operating in the spanish coast by establishing a DGPS National Network (Differential Global Positioning System). The DGPS service facilitates a greater precision for navigation (about 10 meters) in every atmospheric condition, complementando the actual radio navigation techniques through traditional radio beacons, and even improvement of actual precision with aid of ship radars. The coverage area of DGPS service will include a 100 km region paralel to the peninsular and insular littoral.

The Technical Department of Maritime Signals of State Institution “Puertos del Estado” has planned a radioelectric coverage to establish the National DGPS, selecting 17 places of existent or proposed radio beacons in the actual Maritime Signal Plan.

The National Geographic Institute, by its Geodetic Department has collaborated in precision coordinate provision to different DGPS stations installed by “Puertos del Estado”. Thus, in 1999, processing were made in two of them: Estaca de Bares and Finisterre, in Cantábrico, and in 2002, six more points (Cabo San Sebastián, Salou, Castellón, Llobregat, Cala Figuera and Mahón), and in north Mediterranean.

Each of the radio beacons consists of 4 GPS antennas (two of double frequency and two of one frequency). Single frquency antennas are integrity monitors (IM1 and IM2), while the main ones, the double frequency are reference stations (RS1 and RS2). This four antenna´s group is comprised in less than 3 meters between them.

To give coordinates to these stations, GPS permanent stations from National Geographic Institute in La Coruña (ACOR), Mallorca (MALL) and from ICC, EBRE, all of them belonging to EUREF permanent station network and ITRF97 coordinates. Processing with Bernese 4.2 software was done (Astronomical Institute University of Berne), using precise ephemerides from International GPS Service (IGS) and ITRF97 EUREF station coordinates at the observation epoch. Fianl results were tranferred to ETRS89 from ITRF97 (Boucher-Altamimi equations).

The main process features are:

- Pre-processing: phase by using triple differences in baseline mode. Most of cases the cycle slips are simultaneously fixed by different linear combinations of L1 and L2. If a cycle slip are not fixed, the bad data are removed and new ambiguities are fixed.
- Basic observable: Of course, phase carrier. Code is only used to syncronize receiver clocks.
- Elevation mask : 10 degrees.
- Data interval to fix ambiguities : 60 s.
- Data interval of final processing: 180 s.
- Modeled observable: double differencies and ionospheric free combination.
- Phase antenna centre calibrations: corrections to phase center dependent of elevation for different types of antennas, according to IGS calibrations.
- Troposphere: Saastamoinen a priori model.
- Ionosphere: not modelled in final solution, ionosphere removed bye forming free ionosphere combination with L1-L2.
- Orbits and ERP´s (Earth Rotation Parameters): ERP´s and final precise orbits from IGS.
- Ambiguities: QIF strategy (Quasy Ionosphere Free) to fix ambiguities for every baseline. These fixed ambiguities are introduced into final solution.
- Satellite clocks: drifts are not estimated, but removed forming double differences. Receiver´s clocks: drifts estimated during post-processing using code measurements.

Once determined RS1 antenna coordinates, a second Trimble GPSurvey 2.35 pre-processing was done, in order to calculate each IM1,IM2 and RS2 radio beacon coordinates. Data used for this second processing have been 2 hours with a data interval of 1s., enough for such a baseline length (lower than 3 m.) in each radio beacon, introducing IGS precise ephemerides. Choosing any day for every group of antennas, data from 1:00 to 3:00 UTC have been processed, so that tropospheric and ionospheric perturbation is lowest at night.

1. GRAVIMETRY

1.1. Absolute

Since the first absolute measurements of gravity in Spain (J. Barraquer 1877 and 1882) no absolute measurements have been performed till 1989, when Finish Geodetic Institute (FGI) measured in Valle de los Caidos and University of Madrid with JILAG 5. During the last decade of twentieth century, BKG of Germany also performed absolute measurements in Alicante, Granada, Ceuta, Tarifa, and San Fernando with FG5#101.

In 2000 the National Geographic Institute of Spain (IGNE) has purchased a new free fall absolute gravity device by Micro-G Solutions named FG5#211 in order to observe a zero order gravity network in peninsular Spain and at least one point in every island (Balearic Islands and Canary Islands). Also another A-10 absolute gravity meter (10 microgal accuracy) for the first network observation has been purchased in 2001. These networks will serve for geodetic (supporting the new High Precision Levelling Network) and geodynamic purposes.

In 2001 nine stations have been observed by FG5#211 of IGNE: The first station was observed in the library of the National Astronomic Observatory of Madrid, three points at the BIPM during ICAG2001 absolute gravimeter comparison, the Laboratory of gravimetry in the IGN facilities, two points in the CEM (Spanish Center of Metrology in Tres Cantos, Madrid), Geophysical Center of Sonseca (Toledo) and Geophysical Observatory of San Pablo de los Montes (Toledo).

During 2002 absolute stations in Geophysical Observatory of Santiago de Compostela, Geophysical Observatory of Logroño, Geophysical Observatory of Málaga, Geophysical Observatory of San Pablo de los Montes (Toledo), El Miracle (Lleida), Astronomical Observatory of Fabra (Barcelona), Ebro Observatory (Tarragona), El Puig Monastery (Valencia), and Valle de los Caídos (Madrid, IAGBN station) have been observed by FG5#211 of IGNE.

1.1. Relative and UEGN2002

Links between absolute stations and many other densification ones for the REDNAP project have been made. IGNE contributed to the *European Unified Gravity Network (UEGN2002)* sending data from all absolute values known in Spain, as well as relative raw observations.

1. Development of the ED50-ETRS89 datum transition

Introduction

As results of the recently finished REGENTE (National Geodetic Network using Spatial Techniques) have provided us a double set of ETRS89-ED50 coordinates used to prepare a range of transformation techniques. The challenge is to absorb the heterogeneous behaviour of ED50 as a consequence of observational methods evolution, the different calculation for the network, etc. Our purpose is to obtain a single transformation as simple and efficient as possible. In addition, it will be desirable to develop the capability of absorbing local datum changes in shape and form.

Three main techniques have been evaluated: “7 conformal transformation”, “real and complex polynomials” and “minimum curvature surface distortion modelling”. In all those were be used the data of 911 REGENTE points.

6.1. The Methods:

7 parameter conformal transformation

Using the common formulae to this method, three sets of parameters have been obtained in order to keep residuals under 2m. The Iberian Peninsula is divided in two zones: northwest (41º30’N<φ<43º50’N y 9º25’W<λ<4º30’W) and rest . A third set has been computed for Balearic Islands. The 99% of residuals of the adjust were less than 0.99m in the first one, an less than 1.5m in the second one.

Polynomial transformation

Polynomial regression has been used in the past trying to absorb the heterogeneous behaviour of classical networks. The chosen method for Iberian Peninsula has been “progressive elimination”, because is excellent to avoid exclusion of significant variables. The results of this method give us a powerful tool to achieve cartography transformation at mid scales such as National Topographic Map 1:25.000 produced in this institution. The 99% of residuals of the adjust were less than 0.93m when real polynomials were used, and less than 0.60m if complex polynomial is used.

Distortion modelling
There are several methods used in some countries to model such distortion: Least Squares Collocation, Minimum Curvature Surfaces, Multiple Regression, Local Affine Transformation on Delaunay triangulation (Rubber Sheeting), etc. Australia and Canada have applied Collocation and North America Minimum Curvature Surfaces (MCS).

Details about calculation of distortion fields is widely explain in geodetic literature. We have built two grids covering mainland Spain with 105” of interval and 100” for Baleareic Islands. The format chose is NTV2 (National Transformation Version 2), used in Canada and Australia. Such format has the advantage of being used by a large number of software applications.

Test of the obtained grids
In order to test the several methods (Least Squares Collocation, Rubber Sheeting and Minimum Curvature Surfaces) we have created 3 grids, one for each method. The grid was generated using REGENTE monuments (30 Km average distance). For testing the grid a recalculation of the third order network (1400 monuments) was used. The results shows accuracies between 14-18 cm (95%)

Statistics	**E** $_{TEST}$	**N** $_{TEST}$
# points	1400	1400
Average	0.00	-0.01
Std Dev	0.07	0.05
Max	0.24	0.19
Min	-0.25	-0.25
Range	0.49	0.43
95%	0.13	0.11
99%	0.16	0.13

Table 1.points below 25cm. Least Squares Collocation

Estadísticas	**E** $_{TEST}$	**N** $_{TEST}$
# puntos	1395	1395
Media	0.00	-0.00
Std Dev	0.05	0.05
Max	0.23	0.22
Min	-0.24	-0.24
Rango	0.48	0.46
95%	0.10	0.09
99%	0.13	0.12

Table 2. points below 25cm. Rubber-Sheeting

Estadísticas	**E** $_{TEST}$	**N** $_{TEST}$
# puntos	1400	1400
Media	0.01	0.02
Std Dev	0.05	0.05
Max	0.24	0.22
Min	-0.24	-0.24
Rango	0.48	0.46
95%	0.10	0.10
99%	0.13	0.12

Table 3. points below 25cm. Minimum Curvature Surface

6.2. Conclusions

There is no simple way of making datum transformation using standard conformal procedures since the existence of distortion component is difficult to absorb. Modelling the distortion is the best way to perform the datum change.
However, depending on the specialisation level of the user of this transformation a more specific product need to be prepared. An executable software, web page with Java/Asp components, OCX/DLL tools for developers and grid files in NTV2 format will be built. The NTV2 format was developed by the Geodetic Survey Division, Geomatics Canada and it has been implemented in many software packages. The gridding using minimum curvature technique is easy to achieve and gives us the optimal performance in the transformation. The NTV2 format also provides multiple subgrids of different intervals and let us obtain successive grids as the network is being readjusted in ETRS89.

1. RECORD (Radio Broadcasting of GPS Differential Corrections)

The RECORD project intends to broadcast GPS differential corrections through RDS non-audible sub-carrier (Radio Data System) of Radio Nacional de España (RNE) broadcasting stations.

The code differential GPS correction, obtained from pseudodistance observable smoothed with phase, is available in RTCM SC104 format. Further on, it is analysed and compressed in RASANT 2.6 format (Radio Aided Satellite Navigation Technique). It is in this format in which it is sent to RNE, who send it incorporated to the FM signal broadcasted. A FM/RDS/RASANT receiver decompresses and provides the original RTCM SC04 corrections, which are integrable in most GPS receivers.

Since middle of 1997, the IGNE in cooperation with RNE has made several tests to broadcast differential GPS corrections, as requested by quite a lot of users, to manage fleets, to control special public services (burning forests, ambulances, public transport, traffic, and so on.). To do that, the IGNE uses software licenced by LVA of NordRhein-Westfallen, under agreement of exclusive use by IGNE and RNE as free official public service.
The main objective of setting up DGPS/RASANT system (named RECORD) is establishing and implementing a public service to terrestrial positioning available to Spanish community of GPS users with usual criteria of precision, integrity and availability in this kind of systems.

The given service by DGPS/RASANT system will be based upon broadcasting RTCM differential corrections in RASANT format through sub-carrier not audible RDS of RNE broadcasting stations.

The attainment of the objective establishes on a basis of formalization of technical cooperation agreement between IGNE and RNE subscribed to that motive, thus differential corrections will be broadcasted by FM broadcasting stations of the "Red Técnica de Difusión" of RNE. This corrections will be delivered following international accepted formats (RTCM and UIT´s Recommendation nr. 823), compressed in RASANT format, with free access to all users who have a FM/RDS/RASANT receiver.

Precision given by this system will be better than 5 m 2dRMS (95% of probability). In more restrictive conditions concerning to distance to correction generating point and data availability, the system will reached about 1 m precisions.

The DGPS/RASANT system consists of stations DGPS/RASANT and a Control Centre. The DGPS stations that will work in redundant mode by double reference receiver will have the tasks:

- RTCM differential correction generation, evaluation and compression to RASANT format.
- Data deliver to RDS net server of RNE through phone line point to point, optical fibre link or equivalent.

- Working Integrate Monitoring in each station DGPS by decoding RASANT format to RTCM by a FM/RDS/RASANT receiver.
- Observable store setting up a GPS Database.

On its own, the control centre placed in the IGNE facilities in Madrid, will have the following tasks:

- To assure intercommunication with DGPS stations.
- To monitor and control DGPS parameter, assuring system homogeneity.
- To integrate metric precision controls in future peripherical stations.
- To download daily, or by request, of GPS information towards the Spanish National GPS Reference Station Network.

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The fact of being in the peninsular periphery inside a radius of 500 km and positions obtained during the period 1997/98 guarantees that the first part of the network set up will be deal with one control centre and two reference stations, one in Madrid (IGNE) and the other in Sta. Cruz de Tenerife (Geophysical Centre of Canary Islands of the IGNE).

Integrity monitoring tests are being made during 1999-2000. For this reason a triple GPS equipment (2RS+IM) has been set up in IGNE facilities, asuring correction´ s reliability, continuity and integrity for Canary Islands and Peninsula. A forth GPS equipment in Prado del Rey facility to reinforce the array is also working.

The equipments have been set up in Tenerife similar to that in Madrid station and connected to IGNE Control Center in Madrid through RDSI (TCP/IP).

During 1999 a GPS receiver in broadcasting station of Palma de Mallorca has been installed to get an independent solution for the Balearic Islands region apart from that of the peninsula. This solution is available for RNE2 broadcasting stations (Radio Clásica) of Alfabia and Pollensa.

A remote monitoring service is being installed from Prado del Rey by RNE, in which data and audio broadcasting are verified. IGNE has equiped different regional departments with FM/RDS/RASANT+GPS receivers to get a redundant monitorization.

Digital Audio Broadcasting (DAB) tests have been l carried out for the transmission of real time differential phase corrections with excellent results. As long as the technology will be utilised massively this stage of the project is still not operational (RECORD-2)

Digital radio allows a more effective use of the spectrum holding seven programs in one frequency. The PAD (Programme Associated Data) associates data to each program but is space limited for our purposes. The data channel no associated to audio (NPAD) can hold more bandwidth. In this channel is where the tests have been done.

Such tests were done at RNE headquarters, broadcasting the RTCM phase and code differential corrections, that is type 1, 2, 3, 18 and 19. The data was received at a Grundig Dab200 connected to a laptop computer that output the corrections into a test GPS. Several GPS receivers were test: single frequency, double frequency with and without "on the fly" ambiguity resolution option activated. Both GPS, generator and receptor, used in this test shared the same antenna, and the delay observed was about 2 - 4 seconds.

The last part of the project consists on transmitting RTCM over internet (RECORD-3). The BKG has developed all the software (client and server side) for this purposes. The first GPS station included in EUREF-IP is Madrid. This station is located at IE09 monument (ETRS89 class B network) and consist on tree GPS: Integrity monitor+double reference station. Nowadays Madrid station is broadcasting RTCM messages (1,2,3,16,18 and 19) which allows RTK positioning in all Madrid metropolitan area.

In the future some stations of ERGPS will be included in the project although it depends on ERGPS manager objectives. Even if it is not possible GPSL1 mapping reference stations (Córdoba, Coruña and Burgos) will be included as soon as possible.

7 NEW SPANISH HIGH PRECISION LEVELLING NETWORK. REDNAP PROJECT

Between 1997 and 2000, National Geographic Institute of Spain established the High Precision Levelling Network in the Canary Islands. Besides, during 1999 and 2000 replacements and reobservations of High Precision Levelling Network in the Pyrenees spanish zone (INTERREG-2 Project) with an important network length increase in that region, from around 1000 to 1500 kilometers of linear development.

Both tasks, Canary and Pyrenees levelling served as sample for REDNAP Project (High Precision Spanish Levelling Network) which begun to be implementes in 2001 and will end hopefully in 2007, covering the rest of spanish peninsular territory an Balearic Islands. This network is linked to the North Pyrenaic Network, tasks being developed towards South and West with a 2400 and 2500 year rate. All together, in 2008 Spain will have a new network which will cover all peninsular and insular territory with an amount of 17500 kilometers NAP lines

SUMMARY of REDNAP

0 ZONE	MONUMENT DATE	OBSERVATION DATE	NUMBER OF LINES	1 KM
CANARIES	**1997**	**1997-2000**	**15**	**1000**
PYRENEES	**1999**	**1997-2000**	**29**	**1411**
1	**2001**		**38**	**2440**
2	**2002**		**29**	**2404**
3	**2003 (in execution)**	**2004 (programmed)**	**29**	**2400**
4	**The rest till 17500 km is programmed between 2004 and 2007**			
5				
6				
7				

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5.- ROYAL INSTITUTE AND OBSERVATORY OF THE NAVY. (SAN FERNANDO)

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The "Real Instituto y Observatorio de la Armada en San Fernando" (ROA), is a Navy Institution working on geodesy since its foundation on the mid XVIII century. Nowadays, the work on this area is mainly concentrated in Satellites Laser Ranging (SLR) and Global Positioning System (GPS) applications.

1. Satellites Laser Ranging (SLR).

Installed on the top of the main building, under a dome, ROA has a SLR station successively improved since 1968. During the period 1999-2002, the station has been upgraded in the following items:

- Implementation of a Compensated Single Photon Avalanche Diode C-SPAD as detector for nightime tracking.
- New reception system able to use a C-SPAD as well as a photomultiplier as a detector.
- Developing of a new azimuth motor control system to improve the pointing on the satellites.
- General adjust of the laser bench and associated electronic equipment.
- Replacement of the calibration system for a new internal, avoiding refraction effects during calibrations.
- Implementation of the active-passive laser mode, with 50 picosecs and 40 mjoules.
- Substitution of the all electrical power lines by new ones, improving the ratio signal-noise.
- Redesign and implement new electronic circuit boards.
- Main and secondary mirrors periodical repairs.

The above mentioned modifications have been partially funded by the following research projects:

- "Automatic Geophysical Station" (MN-8302), Spanish Defence Ministry Research Programs.
- "An optimization of the precision for the laser observations on artificial satellites" (ESP97-1816-C04-01), from the National Program for Space Research, Comisión Interministerial de Ciencia y Tecnología (CICYT), I+D Spanish National Plan.
- "Daylight tracking on artificial satellites by laser telemetry" (ESP2001-4514-PE), from the National Program for Space Research, 'Ministerio de Ciencia y Tecnología' of Spain.

A brief tracking statistics for the 1999-2002 period are:

- 1999:

SATELITE	N.ECOS	N.PASOS
AJISAI	318262	336
STELLA	91393	270
ERS-1	78277	206
ERS-2	68155	194
LAGEOS-1	99607	231

LAGEOS-2	99648	167
GFO-1	38984	127
STARLETTE	146418	256
WESTPAC	1736	44
TOPEX	219356	258
SUNSAT	17221	78
BEC	72484	135
GEOS	1044	1
TOTALES	1252585	2303

2000:

SATELITE	N.ECOS	N.PASOS
AJISAI	788942	558
STELLA	189438	357
ERS-2	119889	281
LAGEOS-1	203553	218
LAGEOS-2	214530	214
GFO-1	84964	187
STARLETTE	277746	426
WESTPAC	3543	31
TOPEX	586429	434
SUNSAT	12953	76
BEC	452368	488
CHAMP	15144	58
TOTALES:	2949499	3328

2001:

SATELITE	N.ECOS	N.PASOS
AJISAI	359086	317
STELLA	63068	156
ERS-2	37877	107
LAGEOS-1	72072	118
LAGEOS-2	74525	105
GFO-1	30906	70
STARLETTE	123794	239
WESTPAC	260	12
TOPEX	264360	246
BEC	159573	231
CHAMP	13863	56
TOTALES:	1199384	1657

2002:

SATELITE	N.ECOS	N.PASOS
LAGEOS 1	97373	249
LAGEOS 2	74263	174
AJISAI	324485	434
STARLETTE	70906	264
TOPEX	193292	287
STELLA	54258	192
ERS2	64885	258

CHAMP	6437	36
JASON	75844	173
GFO	46610	151
BEC	151851	324
REFLECTOR	15281	137
GRACE A	6107	25
GRACE B	5717	39
METEOR 3	1029	29
TOTALES:	1188338	2772

2. GPS geodetic activity.

The ROA GPS geodetic activity came from the middle 80's. During that period ROA has participated in several field campaings, among which highlihgts the Spanish Antartic research campaings (1987, 88, and so on). It's worth to be mentioned the GPS geodynamic net deployed by ROA in 1994, monumenting several sites south Spain-north Africa, and having a first observation field campaing during that year. This network has been mainly stablished in order to study the geodynamic evolution of the Ibero-Maghrebian region, that is south Spain, Gulf of Cadiz, Alboran sea and north Morocco, region crossed by the Eurasia-Africa plate boundary. During 1994 a Cadiz Bay GPS net was also stablished to study mean sea level variations and oceanographic circulations in that bay.

During the period 1999-2002, the main GPS geodetic activities carried out by ROA have been:

GPS field campaings:

- Collaboration with the University of Porto (Portugal) in October 1999 episodic GPS TANGO-99 campaign, carrying out observations at Monte Hacho, in Ceuta, at Tarifa, and at San Fernando for a 72 hours coverage period.

- Collaboration with the University of Porto (Portugal) in October 2000 episodic GPS TANGO-00 campaign, carrying out observations at Monte Hacho, in Ceuta and at San Fernando for a 72 hours coverage period.

- Collaboration with the University of Porto (Portugal) in October 2001 episodic GPS TANGO-01 campaign, carrying out observations and at the Geographic National Institute of Spain geodetic Monument VS8 located at Monte Hacho, in Ceuta, and at San Fernando for a 72 hours coverage period.

- "Cuateneo-2002" GPS episodic campaing. Organized by the San Fernando Observatory and the University of Barcelona, covering the Cuateneo GPS Network at Murcia and Almeria provinces, end of September, beginning of October 2002. We had the collaboration of University of Cadiz students.

GPS permanent network:

A new GPS permanent station was included in the San Fernando Observatory GPS permanent network. It is located at the 'Observatorio de la Cartuja', in Granada, Spain. It is controlled from San Fernando via Internet, since March 2001. The equipment deployed at that stations is:

- TRIMBLE 4700 receiver.
- TRIMBLE Geodetical antenna.
- Computer.

- UPS + electrical line protection.
- Internet access

GPS at the Spanish Antartic Base:

Also, a GPS permanent station was deployed at the Spanish Antartic Base Juan Carlos I, located at Livingstone Island in the Southern Shetland Islands. It is controlled by the Base team during the base activity period: November-March, collecting the data at the local computers, The data are sent to San Fernando, when the team is coming back to Spain. The equipment deployed at the stations is:

- TRIMBLE 4000 SSi receiver.
- TRIMBLE Geodetical antenna.
- Computer.
- UPS + electrical line protection.

All the GPS data coming both the field campaings and permanent stations, are processed by using the GIPSY-OASIS II software (Jet Propulsion Lab.).

The above mentioned GPS activities have been funded by the following research projects:

- "Automatic Geophysical Station" (MN-8302), Spanish Defence Ministry Research programs.
- "Focal mechanism, crustal deformations, seismotectonics and seismic risk in southern Spain" (AMB97-0975-C02-02), from the National Program for Environment Research, Comision Interministerial de Ciencia y Tecnología (CICYT), I+D Spanish National Plan.
- "GPS Permanent Station at the Spanish Antartic Base Juan Carlos I" (ANT98-1805-E), from the National Programn for Environment Research, Comision Interministerial de Ciencia y Tecnología (CICYT), I+D Spanish National Plan.
- "Meteorological Applications of Global Positioning System Integrated Column water vapor measurements in the western Mediterranean (PL972065). European Comission DGXII/D Fourth Framework Programme. Theme 3, Area 3.3.1.
- "An optimization of the precision for the laser observations on artificial satellites" (ESP97-1816-C04-01), from the National Programn for Space Research, Comision Interministerial de Ciencia y Tecnología (CICYT), I+D Spanish National Plan.
- "GPS campaign at the Cuateneo Network (Almeria – Murcia)" (REM2000-3014-E/RIES), from the 'Ministerio de Ciencia y Tecnología' of Spain.
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6.- VALENCIAN CARTOGRAPHIC INSTITUT. VALENCIA

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Geodetic projects (R. Capilla)

Geodetic, topographic applications, cartographic production and civil engineering projects need a robust infrastructure for their realisation. The Cartographic Institute of Valencia (ICV) has developed several works in this field to fulfil geodetic positioning requirements in the Comunidad Valenciana:

As we know, ETRS89 Datum is accepted as the standard European System of many geodetic and cartographic works. One of the main tasks is the solution for Datum transformation to determine local parameters that fit better the Comunidad Valenciana and the connection of the Fourth Order Geodetic Network with other European Networks like Iberia95 and REGENTE in the Iberian Peninsula. In future, this project will conclude with the adoption of ETRS89 as the Mapping System for the Comunidad Valenciana.

Another point to consider is the maintenance of the Fourth Order Geodetic Network in this area (1521 points). The cooperation between the Institute and de City Councils of the Comunidad Valenciana is decisive in this work. The City Councils inform about the integrity of the geodetic network.

Finally, it is necessary to emphasize the development and update of geodetic tools, that are carried out. For example, geodetic software, coordinates transformation utilities, tools and interface for visualization and diffusion of the geodetic information for the final user.

7. POLITECHNICAL UNIVERSITY OF VALENCIA.

DEPARTMENT OF CARTOGRAPHIC ENGINEERING, GEODESY AND PHOTOGRAMMETRY.

1 GEODESY (Berne, Anquela)

1.1 HIGH-PRECISION LOCAL AND URBAN NETWORKS

The development of this project is focus on two networks, one in Sagunto (Valencia) and the other one in San Miguel de los Reyes' monastery. Climatological conditions are taken into account in the observations. Little displacements have been originated in the points of the networks in order to check the compensation and outlier detections models, apply deformation theory under development and improve precision and reliability based on new error figures theory.

1.2 LOCAL TERRESTRIAL CRUST MOVEMENTS

Two different hill displacements have been studied: Gestalgar and Puebla de Arenoso. The movements in Puebla del Arenoso have been studied with GPS observations. The movements in Gestalgar have been studied with classical observations.

2 GPS (Berne, Quintanilla)

2.1 RASANT

A GPS differential correction station have been developed and located in the building of the Department of Cartographical Engineering, Geodesy and Photogrammetry (Polytechnical University of Valencia), which is a very useful tool for topographical and geodetic applications.

2.2 SOCRATES PROJECT: REAL TIME PURSUIT AND LOCATION OF VEHICLE FLEETS

GPS, MSM-SMS and Rfid Icode have been used simultaneously, the application is supported on digital cartography that can be consulted through Internet. Rfid (Radio Frequency Identification) is a label system that use electronic elements (TAG's) fixed over the objects to identify. This project is a very useful tool for transportation companies.

2.3 GPS AND REFERENCE FRAMES (Berne, Capilla)

A new adjustment of the fourth order geodetic network of the Valencian Community is under development in collaboration with Cartographical Institute of Valencia (ICV). This network in related to REGENTE reference frame (ITRF).

3 GRAVIMETRY (Martín, García)

3.1EARTH-TIDE PARAMETERS OBSERVATION AND DETERMINATION IN VALENCIA

Gravity Earth-Tide observations in Valencia have been analyzed in order to obtain accurate amplitude and phase-difference for the principal tidal waves. The observations have been carried out with the Lacoste&Romberg gravimeter D-203 equipped with electrostatic feed-back system. The data have been digitally recorded since February 2001 with 60 seconds of sampling interval covering a total number of 302 days (434.600 observations). The recorded data have been edited and processed with ETERNA 3.32 Earth-Tide data processing package using the Hartmann and Wenzel tidal potential catalogue.

Finally new tidal parameters for Q1, O1, M1, K1, J1, OO1, 2N2, N2, M2, L2, S2 and M3M6 wave groups are computed for Valencia witch could be of great interest for gravity and geodetic reductions. (More info http://www.upv.es/unigeo/).

3.2GRAVITY NETWORK OF VALENCIA PROVINCE

A new gravity network has been established in Valencia Province to meet the increased requirements of Geophysics, Geology, Geodynamics and Geodesy. The net comprises 21 stations. It has been measured with high precision using 2 Lacoste&Romberg gravimeters between 1999 and 2000, using 1 IGSN71-Station and about 190 relative gravity meter observations. Corrections are applied for Earth-Tides, polar motion, vertical gradient and air pressure. special investigations have been focus on the least-square adjustment with new observations equations. The final adjustment showed a mean standard deviation of 0.018 mGal. (More info http://www.upv.es/unigeo/).

4 LOCAL HIGH-PRECISION GEOID MODEL FOR VALENCIA REGION (Berné, Martín)

High-resolution and high-precision geoid has been computing for Valencia Region, ranging from 37º N to 41º N in latitude and 2º W to 1º E in longitude. The EGM96, complete to degree and order 360, and the GPM98cr, complete to degree and order 720, have been testing, combined with more than 3000 land and marine gravity data and 25m X 25m DTM to generate geoid model. The remove-restore technique was adopted. Second-Helmert condensation reduction has been using for the computation of terrain effects. The contribution of the local gravity data to geoid has been evaluating by least-square prediction and numerical solution of Stokes integral with planar Kernel. The indirect effect of up to second order has been considering. Finally 12 GPS/levelling-derived geoidal heights will be used for local fitting of the geoid witch is essential for a good utilization of GPS for height determination. (More info http://www.upv.es/unigeo/).

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