# Geomatics Cadastral

## Galileo Information Centre for Mexico, Central America and the Caribbean

Implemented by:

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## 1.1 Introduction

Geomatics utilize many geodata collection services and tools for which high precision GNSS is either the paramount tool or a key enabler. Therefore, GNSS is a technique used in a wide range of applications including:

SURVEYING. The surveying sector strongly rely on GNSS-enabled solutions in a number of applications:

- Cadastral in surveying (delineation of property boundaries)
- Construction surveying and monitoring (precise drawing of the future work sites for buildings and infrastructure)
- Mine surveying
- Marine (offshore and hydrographic) surveying


CARTOGRAPHY & MAPPING (charts that contain points of interest and are typically integrated in Geographic Information Systems)

**What is Cadastral?**

Cadastral is one of GNSS priority applications in the Geomatics sector (together with Cartography & Mapping). It is a particular type of precise surveying which aim is precisely defining and measuring specific location points of interest and current real property boundaries, for cartographic and urban planning purposes.

In more words, cadastral surveying is the sub-field of land surveying that involves the determination of the legal boundaries of land properties. Thus, in order to establish or re-establish the property boundaries, land surveyors proceed with the three steps, i.e. research, field operations and (legal) drafting. Once the appropriate evidence found in land deeds, cadastral registers, recorded past surveys, subdivision plats, topographic maps, etc. has been analysed, the surveyors set out into the field to gather horizontal (and potentially vertical) data of physical objects on the property in question and those adjacent to it, for comparison to the research (historic) data [1].

In spite of there are different techniques used in cadastral, GNSS holds a predominant position within the different technological solutions allowing to achieve the desired accuracy and confidence. In fact, GNSS is an essential technique in which surveyors and rely on.

## 1.2 State of the art and trends in geomatics

GNSS-enabled equipment has been an integral component of the surveyors' and mappers' toolbox already since the late 1980s and today is much more essential being widely used in a great variety of surveying and mapping tasks, due to significant improvements in receiver technologies, higher availability of signals in the advent of the multi-GNSS era and marked progress in terms of price and usability.

One evidence of the importance of GNSS is the growth of GNSS devices in the overall surveying sector in the last decade, especially in cadastral, construction and mapping applications.

Main trends and market overview of geomatics are:

- Growing of GNSS devices in Geomatics, specifically those that use Galileo.

  Between 2021 and 2031 annual shipments of GNSS receivers are forecasted to grow from 1.8 billion units to 2.5 billion units. Two are the main factors that contribute to this fostering:

  - Construction sector in emerging markets, that is, the rely in positioning of construction market in a great extent
  - Drop of the prices and new technology solutions.

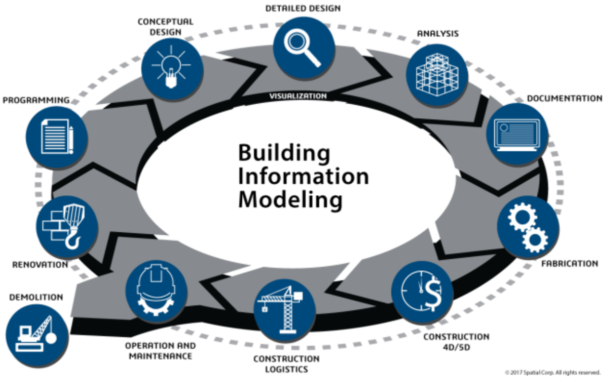
- Service of PPP-RTK: allows to improve accuracy and improve measurement time and processing time

- Growing of drones applications and new positioning techniques: used for cartography and photogrammetry where positioning is very important. New UAV uses GNSS sensors that are able to receive Galileo signals allowing to determine central positioning and therefore in an accurate way, achieving accurate cartography products.

[1] *Report on User Needs and Requirements Mapping Surveying (EUSPA)*

In particular, it is relevant to mention the importance of the drone regulation in cities, that is, to fly drones in cities. In this regard, taking the cadastral GNSS surveyor off a heavy traffic street or the mapping drone away from the crowd below, without loss of operability and accuracy, will continue to be the challenge for the urban geomatics market.

- Building Information Modelling (BIM) adds value to infrastructure projects. GNSS contributes to the positioning of the building. BIM is a new concept for building and infrastructure construction: the location and attributes of structures are saved and shared throughout the entire construction life cycle.




- Simultaneous Localization And Mapping (SLAM): SLAM is "the computational problem of building or updating a map of an unknown environment while calculating an agent's position within it." GNSS converges with SLAM in the outdoor realm, along with other sensors: laser scanners (2D LiDAR, phase-based scanners), inertial devices, odometers, and cameras. Accuracy is essential, and GNSS gives a good answer.

- Mobile mapping is same as SLAM but when the focus is on map generation. n this case, the position of the rover is obtained in advance with high precision (via network RTK, for example) so that there are fewer degrees of freedom in determining the map features

- Augmented Reality (AR): the impact of ARis growing – GNSS is a cost efficient enabler of AR in mass market devices. Augmented reality is the fastest growing area of high-precision GNSS and is finding new use cases every day in the domains of geomatics, mapping and GIS.

- Crowdsourcing consists of the on-demand availability of computing resources, especially storage and processing power, without direct active management by the user.

- Cloud processing: there are many GNSS services that are provided from “the cloud”. The simplest example: GNSS data repositories (RINEX, IONEX).

## 1.3 GNSS techniques in cadastral and surveying

Several sectors including land surveying (cadastral, construction and mine), mapping and marine surveying (marine cadastre, hydrographic and offshore surveys) benefit from the proliferation of high accuracy GNSS-based solutions. Multi-constellation and multi-frequency receivers, as well as various differential correction techniques (SBAS, RTK and DGNSS) are currently deployed in the surveying and mapping sector.

The different GNSS technique are presented in the next figure:

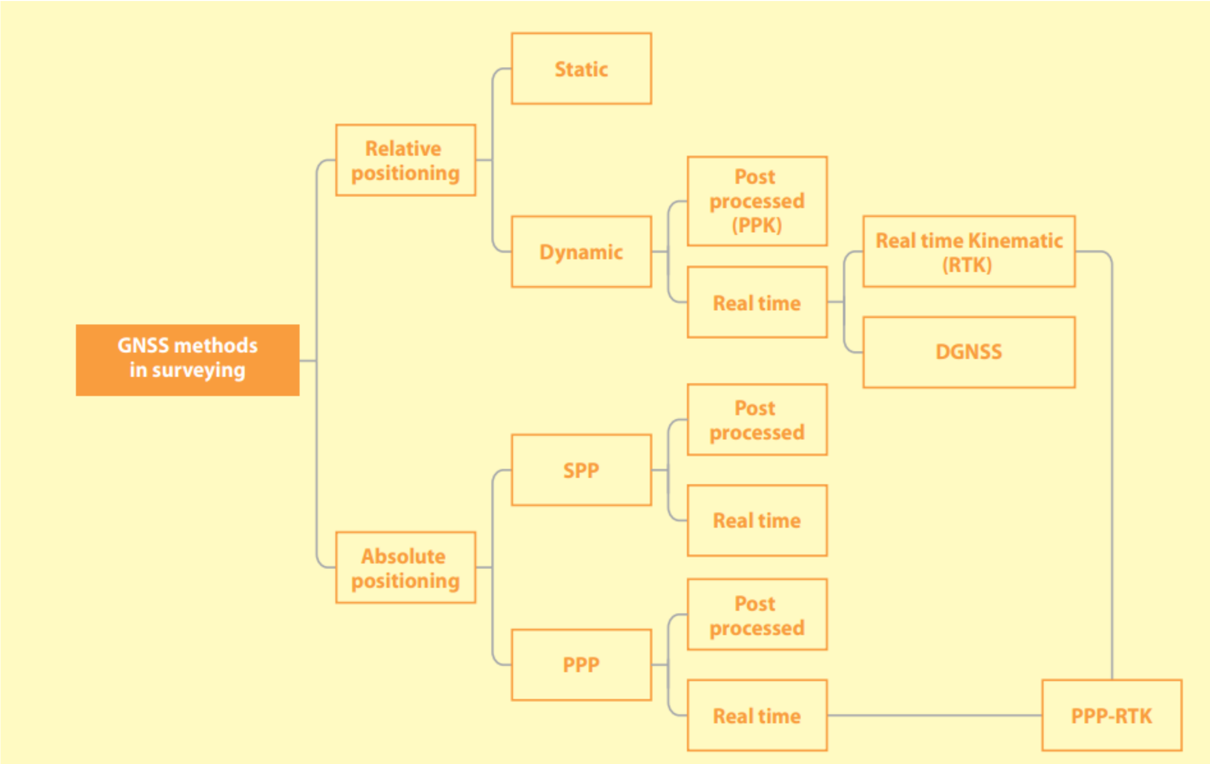



Figure 1: Total Overview of different GNSS techniques deployed in surveying

The techniques and solutions used for surveying are dependent of the user requirements and criterion[2]. One of the most relevant criterion is the accuracy. In general, the accuracy performance level goes from mm to m in surveying.

In particular, most cadastral maps need to be at scales of **between 1:500 and 1:2,500** although in densely developed areas a larger scale may be needed while in open countryside much smaller scales may be acceptable. This scales means that submetric accuracy is necessary and could be met with **Galileo**, depending of the specific task to carry out in cadastral.

Augmentation services, including new techniques such as PPP-RTK, are becoming an important tool not only for cadastral surveying, but also for mapping and GIS activities. Nevertheless, **satellite-based augmentation systems**, such as the WAAS system in the United States and the European Geostationary Navigation System (**EGNOS**), which allow differential correction to be carried out, an important aspect to consider in the region is that **they do not have coverage** in most of the region.

WAAS currently covers the regions of Alaska, Canada, the United States and Mexico, while EGNOS has coverage in the European Union and some neighbouring regions. In 2013 a project called SACCSA (Sistema de Aumentación para el Caribe, Centro y Sudamérica) was presented by the International Civil Aviation Organization, to analyse the technical, financial and institutional feasibility of implementing an SBAS / GNSS system for the region. However, **to date there is no real implementation.**

## 1.4 EGNSS benefits for cadastral

GNSS measurements are used in cadastral measurements. Some of the advantages of GNSS surveying with respect to conventional methods in cadastral survey is given below (*Tamrakar, 2013*).

- Inter-visibility between consequent stations are not required,
- Traverse stages in the field for providing control points for classic surveys are not needed
- Establishment of the control points is more accurate, easier with less cost
- The measurements can be made in day time and at night, under almost all weather conditions

[2] *Report on User Needs and Requirements Mapping Surveying (EUSPA)*

- Simple field operation
- Continuous 3D positioning
- All coordinates can be estimated in a global datum, i.e. ITRFyy or so on

Nevertheless, conventional terrestrial methods/equipment; i.e. steel band, EDM, theodolite and for a couple of decades total stations and etc are still required in surveying applications, including cadastral. Although the GNSS systems have considerably facilitated the measurements, there are still some limitations in their usability in some cases like in densely urban areas, mountains, heavy tree cover, ravines and similar places.

Therefore, even though the combination of GPS and secondary satellite system like GLONASS or Galileo observations can overcome the abovementioned problems, conventional surveying techniques are still required in some instances, but it is recommended to explore the advantages and performances in the specific case.

In particular, Galileo, the European GNSS system offer specific advantages.

**<u>How to benefit from Galileo?</u>**

- High Accuracy Services (HAS) enables
    - GLOBAL positioning with accuracies < 20 cm (H) / 40 cm (V)
    - Improved convergence for the Regional Service

The HAS will provide much higher continuity of cadastral or mapping/GIS GNSS operations in urban territories

- Multi frequency enables to have
    - Better results in hars (urban canyons, tree canopy, etc),
    - Increased availability, continuity and reliability of measurements
    - Improved convergence time when integrated in PPP solutions.

According to the experiences from studies[3], the use of single frequency GNSS mass-market receivers can be considered useful for cadastral surveys with some adjustments, therefore Galileo (multi frequency) adds an extra value. If the distance between master and rover receivers is less than 5 km, a single-base methodology can be exploited while if the inter-station distance increase it is better to use the NRTK positioning, if a CORS network is available. These results open new perspectives in the GNSS cadastral surveys, allowing to use portable and low-cost

[3] The usability of GNSS mass-market receivers for cadastral surveys considering RTK and NRTK techniques P.Dabove 2019

devices without loosing accuracy or precision in the estimation of points' coordinates (https://www.sciencedirect.com/science/article/pii/S1674984718301733)

- Authentication features that avoid the spoofing, the emerging threat:
  - OSNM OS Navigation Messsage Authentication is the special encryption capability for Galileo Messages to garantee to the users that they are utilizing non counterfeit navigation data that comes from the Galileo satellites and not from any other sources
  - CAS Commercial Authentication Service to protect against to sophisticated atacks, increasing the robustness of profesional applications

Authentication is being identified as important by an increasing number of users, especially in building construction, where lack of proper GNSS signals may result in projects falling behind schedule, incurring damages or lowering personnel safety

In summary, the benefits of Galileo, is general terms, and also applicable to cadastral are:

- Multipath mitigation (for example, for working within the tall city skyline)
- Greater availability
- Higher accuracy
- Greater continuity
- Shorter time to First Fix

## 1.5 Commercial opportunities

The predominant uses of GNSS in the professional field are surveying and geodetic applications, which, in the region of Mexico, Central America and the Caribbean is developed mainly by independent professionals, in many cases grouped into professional associations and by government institutions that regulate and control geospatial information. In addition, Governmental institutions dedicated to geospatial administration in different countries.

Examples of actors:

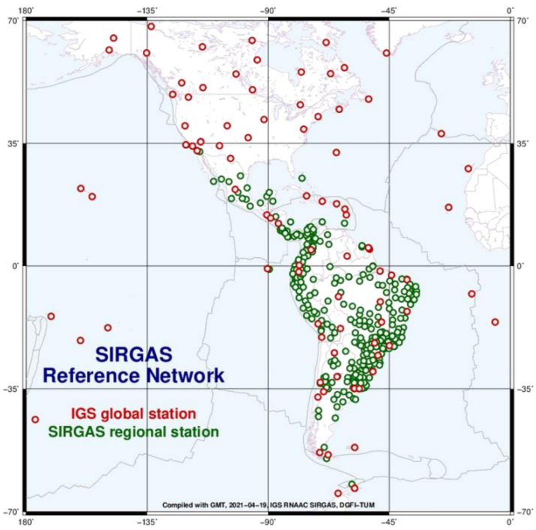
- The “Federación de Organizaciones de Ingenieros de Centroamérica y Panamá” (FOICAP)

- The "Asociación Panamericana de Profesionales de la Agrimensura y Topografía" (APPAT), founded in 1999 at the initiative of the Professional Associations of Puerto Rico, the Dominican Republic, Argentina and Uruguay. It operated for some years and for various reasons was inactive, reactivated again in 2007 with the participation of representatives from Panama, Mexico, Venezuela, Colombia and Costa Rica.

### 1.5.1 GNSS networks and reference systems in America

- SIRGAS (Sistema de Referencia Geocéntrico para Las Américas):

SIRGAS is established in the region. Its definition is identical to that of the International Terrestrial Reference System (ITRS) and its realization is a regional densification of the International Terrestrial Reference Frame (ITRF) product of the densification of a network of high-precision GNSS stations in Latin America. SIRGAS, as an organization, is responsible for materializing and maintaining Latin America's threedimensional geocentric reference system, including a unified physical height system of global consistency. The SIRGAS continuous-operated network (SIRGAS-CON) is currently composed of about 400 stations distributed in Latin America. (SIRGAS-C), primary densification of ITRF in Latin America, with stable, optimally operated stations that ensure consistency, durability and accuracy of the frame of reference over time. It comprises a continental coverage network (SIRGAS-C) and national reference networks (SIRGAS-N), which densify the continental network and provide access to the reference framework at the national and local level[4].




[4] http://www.sirgas.org/es/sirgas-con-network/

Figure 2: SIRGAS reference network

Currently there are national networks of SIRGAS in Mexico, El Salvador, Costa Rica, Panama and Venezuela among others. An event was recently held on the part of the SIRGAS organization aimed at establishing the continuous GNSS network of the Dominican Republic

### *1.5.2 Mexico*

- ACOMITAC "Asociación de Colegios Mexicanos de Ingenieros Topógrafos:

AC (ACOMITAC), was established in 2009 and includes professional associations in the states of Puebla, Jalisco, Guerrero, León, Veracruz, among others. In Mexico, INEGI is an autonomous public body responsible for regulating and coordinating the National System of Statistical and Geographic Information. INEGI manages the **Active National Geodetic Network**, a set of permanent operating stations that record data from the Global Satellite Navigation System (GNSS), strategically distributed throughout the national territory, which materialize the National Geodetic System in its horizontal aspect, and provide geodetic positioning services to users through online data and coordinates of the highest positional accuracy in the country.


Figure 3: SIRGAS reference network

### *1.5.3 Central America*

In Central America there are different professional groups. In Guatemala there is a **Geodesy and Geomatics Commission** attached to the Guatemalan College of

Engineers. In Costa Rica there is the **College of Topographical Engineers** that is part of the Federated College of Engineers and Architects.

- "Instituto Geográfico Nacional" in Costa Rica

  In Costa Rica, IGN is part of the National Registry, is the body in charge of developing and implementing the "Marco Geodésico Dinámico Nacional" (Margedin). It has a network of continuous measurement GNSS stations that in turn constitute vertices of the SIRGAS-CON continental network.Costa Rica


Figure 4: GNSS stations in Costa Rica

The Margedin project aims to develop and implement the National Dynamic Geodetic Framework, an official platform for the monitoring of changes and precise, timely, agile and quality georeferencing that allows satisfying the information generation needs in geodetic and geophysical matters. They are the basis for the georeferencing processes of the official boundaries, the cadastral map and are an input for legal security, planning and land use. Its objectives include maintaining the current network of GNSS stations and making technological change in the network. In this change, they contemplate that the renewal of the GNSS equipment must occur mainly due to the changes in the architecture of the new GNSS receivers. And at this point they bear in mind that in the European Union will have 30 more satellites in the Galileo constellation and the Federal Republic of China will have 30 more satellites in its BeiDou constellation. Apart from the full and operational GNSS constellations of GPS and GLONASS.

- Instituto Geográfico Nacional, Ing. Alfredo Obiols Gómez in Guatemala

In Guatemala, IGN is a dependency of the "Ministerio de Agricultura, Ganadería y Alimentación", technical scientific, rector and provider of products and services, which prepares and guarantees reliable geographic and cartographic information for research, planning and monitoring. The CORS network in Guatemala currently consists of 17 stations spread throughout the national territory. These stations are located in strategic points of the country.


Figure 5: CORS Guatemala station network

The CORS network is a geodetic network of continuously operating reference stations, or CORS for its acronym in English (Continuously Operating Reference Station). A CORS station is basically composed of a static GPS receiver that is permanently positioned in a known geographic location, and collects data 24 hours a day, 7 days a week. These data are transmitted through a computer network to a central server, where they are stored for later use. The operation of the Reference Stations for Continuous Operation –CORS– will allow cadastral surveys to be carried out quickly and efficiently throughout the Republic of Guatemala.

- Dirección General de Catastro y Geografía in Honduras

In Honduras, the “Dirección General de Catastro y Geografía”, has within its functions Maintaining and densifying the national Geodetic network. Honduras has passive geodesic networks for cadastral purposes in the most important cities of the country. In addition, there are also active stations in Tegucigalpa, Juticalpa, Siguatepeque and San Pedro Sula.

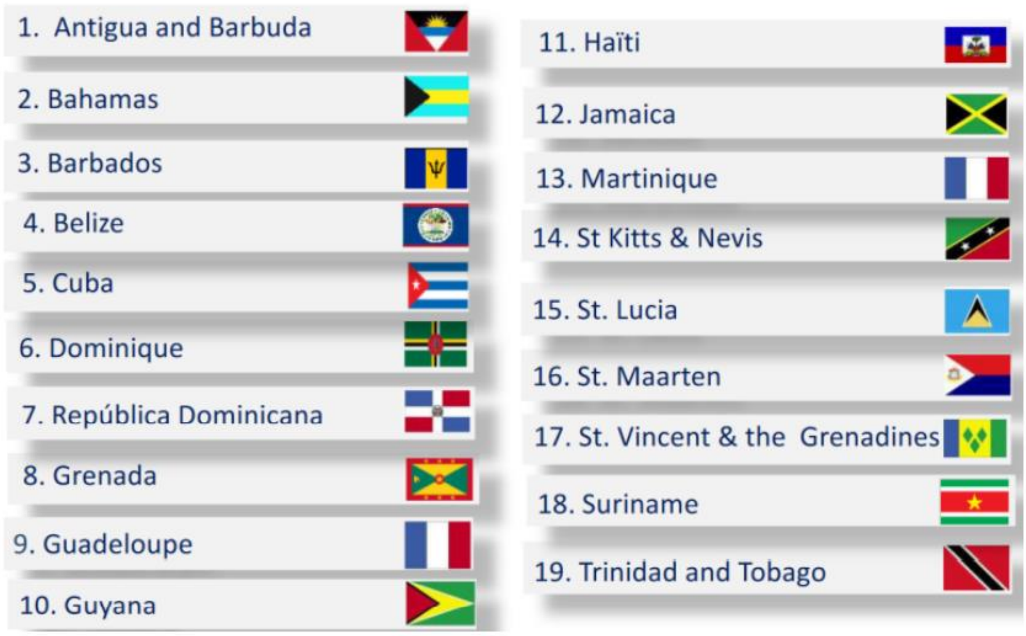
- “Instituto Geográfico Nacional Tommy Guardia in Panama

It is the institution in charge of the National Network of Reference Stations of Continuous Operation. To date, the institute has 19 CORS stations, 7 of which are part of the SIRGAS-CON Continental Network. Among the objectives of the CORS National Network are the following: • Provide updated geodetic information for cartographic preparation, cadastral surveys, and engineering projects, among others. • Serve as support for land and sea navigation and especially international air navigation. • Improve and update the global geodetic frame and therefore the national geodetic frame. • Provide the necessary elements that allow scientific studies to be carried out on the determination of the movements of the earth's crust. • Provide data that can be used for analysis and early warning of earthquakes and tsunamis, among others. • Collaborate in the study of the effects of climate change, by analyzing the data obtained from the GNSS satellites.

### 1.5.4 Caribbean

There is currently a project[5] to promote the development of Space Data Infrastructures in the Caribbean to strengthen the production, use and exchange of geospatial information for decision-making. The project's objectives include strengthening the region's geodesic network.

The figure below presents all the Caribbean countries that are the object of our study are part of this project




[5] Proyecto caribe (sirgas.org)

Figure 6: Caribe Project. Participating countries.

There are currently 16 GNSS stations installed in 12 Caribbean countries , as depicted below:

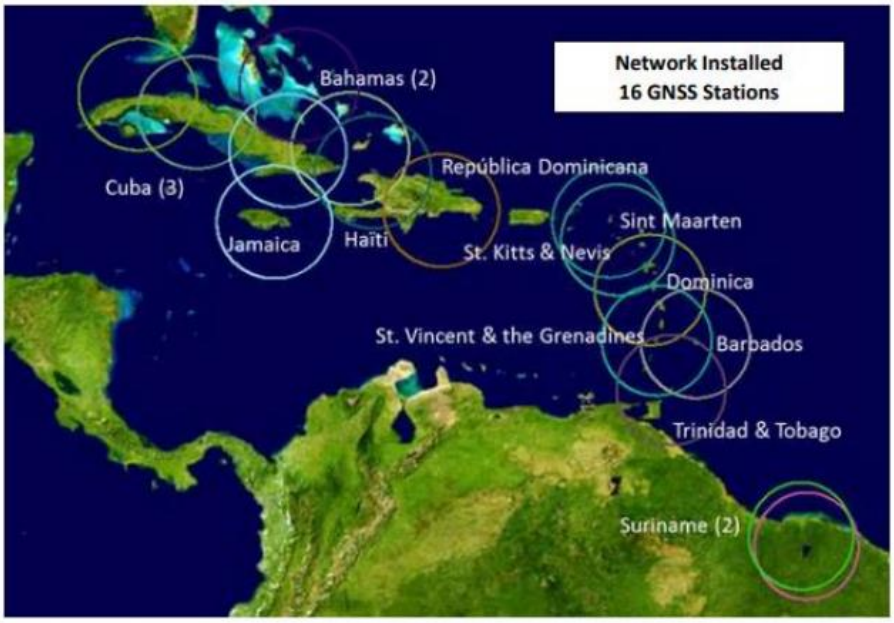



Figure 7: Caribbean GNSS Station Network

- Instituto Geográfico Nacional José Joaquín Hungría Morell (IGN-JJHM) in the Dominican Republic

In the Dominican Republic, the “Instituto Geográfico Nacional José Joaquín Hungría Morell" (IGN-JJHM), is responsible for the formulation of public policies and actions in the areas of geography, cartography and geodesy. The liberal exercise of engineering and agromensura is regulated by the “Colegio Dominicano de Ingenieros, Arquitectos y Agrimensores” (CODIA). The Government of the Dominican Republic considers important the creation and unification of the National Geodetic Network that will benefit different institutions with quality information. The IGN seeks to establish a public-private alliance with the main actors in the management and use of these networks, in order to reach the strategic guidelines to develop and consolidate the geodetic issue on a national scale. • Cuba In Cuba, the “Unión Nacional de Arquitectos e Ingenieros de la Construcción de Cuba”, identified with the acronym UNAICC, has as its fundamental objective, to achieve the integration of all professionals linked to the construction sector.

### *1.5.5 Venezuela*

- Instituto Geográfico de Venezuela Simón Bolívar

In Venezuela, IGN governs the technical standards for the formation and densification of the “Red Geodésica de Venezuela” (REGVEN), which is part of the SIRGAS Network in South America. Venezuela participated in SIRGAS campaigns in 1995 and 2000 with 5 and 11 stations respectively. The SIRGAS-REGVEN datum was officialized in 1999. The REGVEN network has 90 GNSS stations measured simultaneously with SIRGAS 95 and subsequently re-ordered in 2000. In addition, there are 8 continuous measuring stations (REMOS). In 2015, a measurement of 134 REGVEN vertices was made to determine variants with the 1995 and 2000 networks.

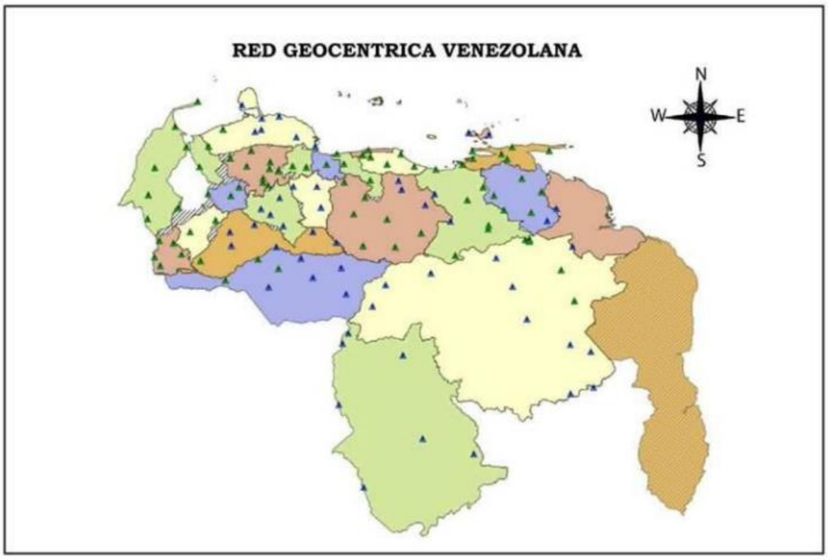



Figure 8: Venezuelan Geocentric Network

For its part, the “Colegio de Ingenieros de Venezuela” (CIV) is the body that regulates the exercise of Engineering, Architecture and Related Professions.

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