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Transportable Integrated Geodetic Observatory (TIGO)

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Abstract

TIGO is a transportable fundamental station for geodesy. TIGO consists of VLBI and SLR modules as well as of a so called basic service module which comprise a GPS array, atomic clock ensemble, superconducting gravity meter, seismometer, meteorological sensors including a water vapour radiometer and a server for the LAN. The energy module allows the operation of TIGO at remote sites with little infrastructure.

The primary purpose of TIGO is to contribute to the realization of global reference systems for geodesy (ITRF). Its transportability allows us to place TIGO at a site which improves homogeneity in the network of fundamental stations within the ITRF, if the necessary support of the hosting country can be made available to this project. After an Announcement of Opportunity for hosting TIGO and a reconnaissance of proposed sites as well as some analysis concerning the optimal use of TIGO, the Chilean city of Concepción got the highest priority for hosting TIGO beginning 2001.

1. Objectives of TIGO

The global reference frames ICRF (International Celestial Reference Frame) and ITRF (International Terrestrial Reference Frame) are the basis for all geodetic reference frames applied in continental and national areas. Today the geodetic space techniques are highly efficient and cost effective for scientific and practical applications. The geodetic space techniques such as VLBI (Very Long Baseline Interferometry), SLR (Satellite Laser Ranging), and microwave based observations of navigation systems like GPS (Global Positioning System) and DORIS (Doppler Orbitography and Radiolocation Integrated by Satellite) are realizing the global reference frame ITRF through an international network of geodetic stations—the International Space Geodetic Network (ISGN)—consisting of radio telescopes for VLBI, laser ranging systems for SLR/LLR, permanent GPS stations, DORIS ground beacons.

The global distribution of the geodetic stations is inhomogeneous. Concentrations of stations occur in North America, Europe and parts of Asia (Japan), whereas gaps in the network are obviously on the southern hemisphere.

For the minimization of systematic effects and errors the ideal distribution for the ISGN would be a homogeneous network. It is obvious that the realisation is an international task, regardless of political borders. International and bilateral cooperations are required, which finally result in the benefit for all by the existence of a highly precise global reference frame. The international coordination of the contributions is performed through the international services which are under the patronage of the International Association of Geodesy (IAG), namely the IVS (International VLBI Service)[1], ILRS (International Laser Ranging Service)[2], IGS (International GPS Service)[3].

[1] http://ivscc.gsfc.nasa.gov/
[2] http://ilrs.gsfc.nasa.gov/ilrs_home.html
[3] http://igscb.jpl.nasa.gov/

The combination of the products is guaranteed through the IERS (International Earth Rotation Service)[4].

The Bundesamt für Kartographie und Geodäsie (BKG) has developed the Transportable Integrated Geodetic Observatory (TIGO) as an additional fundamental station for the support of the realisation and for the maintenance of the ITRF and ICRF. TIGO is currently in a test phase and is operated in collocation with the Fundamentalstation Wettzell in Germany. It is planned to start the regular field operations in the year 2001. Due to the transportability the contribution to the ITRF can be optimised in dependence of the location and of the duration of operation at one site. In order to fill gaps in the ISGN the area for operation is preferably on the southern hemisphere. The minimum operation period at foreign sites is envisaged to be three years.

2. Transportable Integrated Geodetic Observatory (TIGO)

TIGO is a rigorous development of a fundamental station in order to provide observations for the

1. realisation of the geodetic global reference system,
2. maintenance of the global reference frame,
3. monitoring of the Earth orientation parameters,
4. monitoring of the crustal movements including tides.

All relevant geodetic space techniques are employed at TIGO:

- Very Long Baseline Interferometry (VLBI),
- Satellite Laser Ranging (SLR),
- Global Positioning System (GPS) and comparable navigation systems.

For the performance of observations with geodetic space techniques and for the correct interpretation of observational data additional local measurements are indispensable, like

- measurements concerning the local time and frequency keeping providing the UTC related time scale and reference frequencies,
- gravity measurements for monitoring Earth tides,
- seismic measurements for monitoring earthquakes,
- meteorological measurements for monitoring the troposphere,
- local survey measurements for monitoring the site stability and eccentricities between the various instrumental reference points.

TIGO has its own electric power generators in case there is no or unstable power supply at the remote site.

Transportability of the observatory is achieved by building the whole observatory into six 40-foot standard containers, which are certified for sea transportation. It is assumed that according to its specifications TIGO can be shipped to any remote location (outside arctic or antarctic environments) in the world. The un-/loading procedure of the containers from/to a truck at the selected

[4]http://hpiers.obspm.fr/

TIGO site is possible simply with muscle power (no crane will be needed!). After installation of TIGO some of the containers serve as the operation rooms. A more detailed description can be found in [3].

It is planned that TIGO will be operated jointly by BKG and partner institutions of the hosting country. With respect to the necessary training of staff and the risks of transportation the period of operation at the remote site should be at least three years.

3. TIGO in the Network of Fundamental Stations

Fundamental stations for geodesy realize fundamental reference points within the ITRF because of the possibility to tie global networks of different geodetic space techniques at one location by the local survey of the eccentricities between the various instrumental reference points.

In 1999 the ITRF contained only a few sites which deserve the title of a fundamental station. These are *Wettzell* (Germany), *Matera* (Italy), *KeyStone* (Japan), *Greenbelt*, (U.S.A.).

In addition there are some quasi-fundamental stations, where the distances between the different instruments are larger than 1 km. This makes the local survey more difficult, because its accuracy level should be one order of magnitude more accurate than those of the geodetic space techniques. However the results from these stations represent within a global reference frame the same region and are subject to almost the same geodynamic phenomena. The list of these stations consists of *Shanghai* (P.R.China), *Canberra-Tidbinbilla* (Australia), *Kokee Park-Maui* (Hawaii). An additional fundamental station at *Hartebeesthoek* (R.S.A.) will be created with the beginning of a permanent SLR operation with MOBLAS-6.

The TIGO project must be seen as a German contribution to the international effort to realize and to maintain the most accurate global reference system by densifying the existing networks. TIGO as a transportable fundamental station has the ability to be placed on those sites which contribute in an ideal way to the process of homogenisation of the inhomogeneous global network of fundamental stations.

A computation method in order to locate the most distant point from an existing point distribution on a sphere was developed by Hase [2]. Figure 1 shows the existing network of fundamental stations and the areas which they represent in terms of distance to other stations. From figure 1 it can be easily seen, that an additional fundamental station in South America would close the largest gap in the network.

Even if the choice for the best location can be quantified by the method described above, TIGO is dependent on the support by the hosting country in terms of operational staff, cost sharing and property provision. In July 1999 an *Announcement of Opportunity* for hosting TIGO was published by BKG [1]. By the due date September 30, 1999, several institutions from countries in South America and in near and far East Asia applied for participation in the TIGO project. During November and December 1999 the most promising 11 sites were inspected by BKG staff. A report [4] on the reconaissance and the received *Letters of Intent* were presented to the directing board of the German research group on satellite geodesy (FGS) who initiated the TIGO project in the early nineties.

Among the competitors a consortium with the Universidad de Concepción as main partner in Concepción, Chile, got the highest priority for hosting TIGO because of fulfilling the request from BKG for hosting and operating TIGO as well as the ideal geographical location within the global reference networks. A second priority was given to Cordoba, Argentina, and Bangalore, India.

Figure 1. Voronoi diagram with existing (quasi-)fundamental stations (marked with stars). The voronoi lines are the lines of largest distance between stations. The three numbered voronoi vertices are the three most remote points in the network of existing stations.

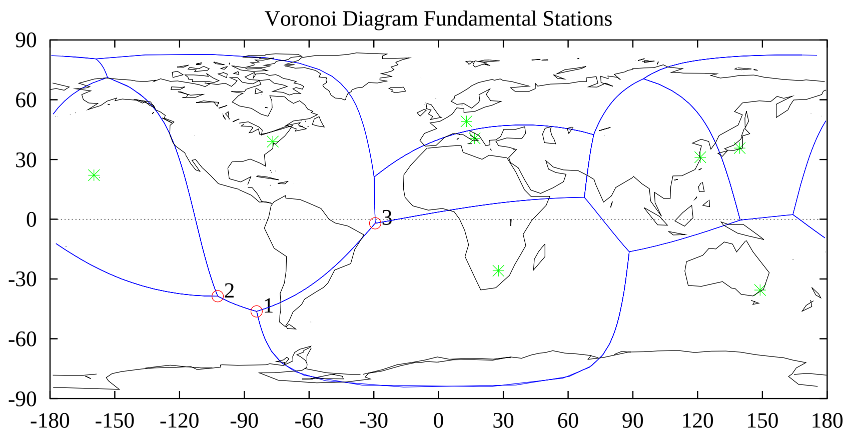
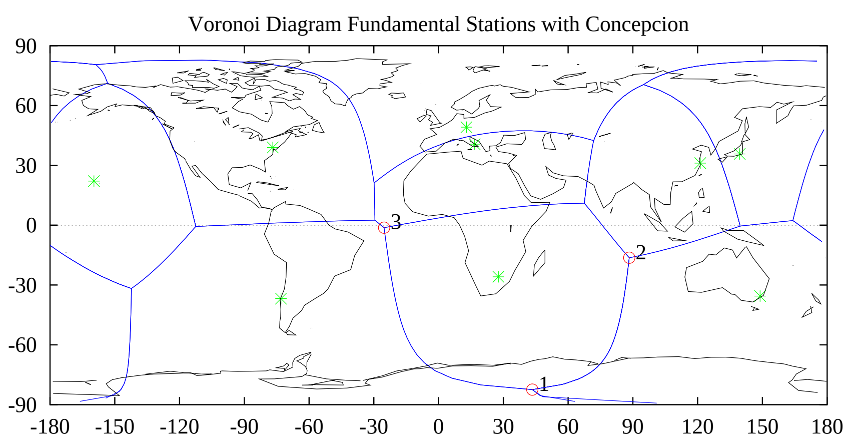


Figure 2 gives an impression of how the network changes in terms of approaching homogeneity in its point distribution by adding one new sites near the most remote locations (resp. close to the center of the largest gap).

Figure 2. Voronoi diagram with the network of existing (quasi-)fundamental stations plus the new site of Concepción possibly occupied with TIGO in the near future. (Compare with fig. 1.)



The gain of an additional fundamental station in the southern part of South America can be expressed in terms of the decrease of the maximum distance between the most remote point to any fundamental station (largest gap). Table 1 summarizes the gains of South American applicants.

Another way of looking at the improvement through an additional fundamental station in the network can be derived by the approximate volume of the Earth which follows from a Delaunay

Table 1. Improvement by an additional fundamental station in terms of reducing the largest distance to the fundamental points on a unit sphere Earth model.

New Site	Largest Distance	Gain
none	8648 km	0 (ref.)
Concepción, Chile	6087 km	29.6%
Cordoba, Argentina	6351 km	26.5%
Buenos Aires, Argentina	6486 km	25.0%
Fortaleza, Brazil	7758 km	10.3%

triangulation among the fundamental points on a unit sphere Earth model. Table 2 shows the increase in the approximate volume due to one additional site at different locations in the given network. The large relative increase of more than 57% can be achieved in South America with the realisation of an additional fundamental point by TIGO.

Table 2. Increase of volume of the unit sphere Earth model. Earth's approximate volume is derived from a Delaunay triangulation in the network of the fundamental stations. The listed sites had been proposed for hosting TIGO.

New Site	Volume	Increase
none	0.9727	0 (ref.)
Concepción, Chile	1.5294	57.2%
Cordoba, Argentina	1.5196	56.2%
Buenos Aires, Argentina	1.5129	55.5%
Fortaleza, Brazil	1.3085	34.5%
Bangalore, India	1.1537	18.6%
Serpong, Indonesia	1.1152	14.6%
Quezon City, Philippine	1.0278	5.7%

The next steps within the TIGO project comprises the negotiations with the Universidad de Concepción about the details of setting up TIGO and the operation beginning 2001 for a minimum period of three years.

References

[1] Announcement of Opportunity on Hosting TIGO, http://www.wettzell.ifag.de/tigo

[2] Hase, H.: New Method for the Selection of Additional Sites for the Homogenisation of an Inhomogeneous Cospherical Point Distribution, in: Int. Ass. of Geodesy Proceedings, Towards an Integrated Global Geodetic Observing System (IGGOS), Munich, October 5-9, 1998, edited by R. Rummel, H. Drewes, W. Bosch, H. Hornik

[3] Hase, H.: Theorie und Praxis globaler Bezugssysteme, Mitteilungen des Bundesamtes für Kartographie und Geodäsie, Band 13, Frankfurt am Main, 1999

[4] Schlüter, W., Hase, H.: Bericht zur Entscheidungsfindung über den ersten ausländischen TIGO-Standort, BKG-G-Az. 5165, 16. Januar 2000 (internal document)