ADELA 2016 - COLOMBIA

Co-location satellite GPS and SLR geodetic techniques at the Felix Aguilar Astronomical Observatory of San Juan, Argentina

R. Podestá , A. M. Pacheco , H. Alvis Rojas , J. Quinteros ,
F. Podestá , E. Albornoz , A. Navarro y M. Luna

This presentation shows the strategy followed to get the mathematical co-locations between SLR telescope and permanent station GPS antenna, in the Felix Aguilar Astronomical Observatory of San Juan, Argentina

The work allows the coordinates of the Station can be obtained by combining data from both techniques and greater level of accuracy than each individually.

The IERS considers stations co-localized as the points more valuable and important for maintaining the Terrestrial and Celestial Reference Systems.

SAN JUAN - ARGENTINA

Surface: 89.651 Km²

Population: 700000 people

Density: 7 people / Km²

Weather: Sunny and Dry

Félix Aguilar Astronomical Observatory

System and Frame References

- **Reference System (RS) is a geometric structure that serves to refer the coordinates of points in space. It can be defined by three axes with its origin and directions, scales, algorithms spatial-temporary transformations and constant.**

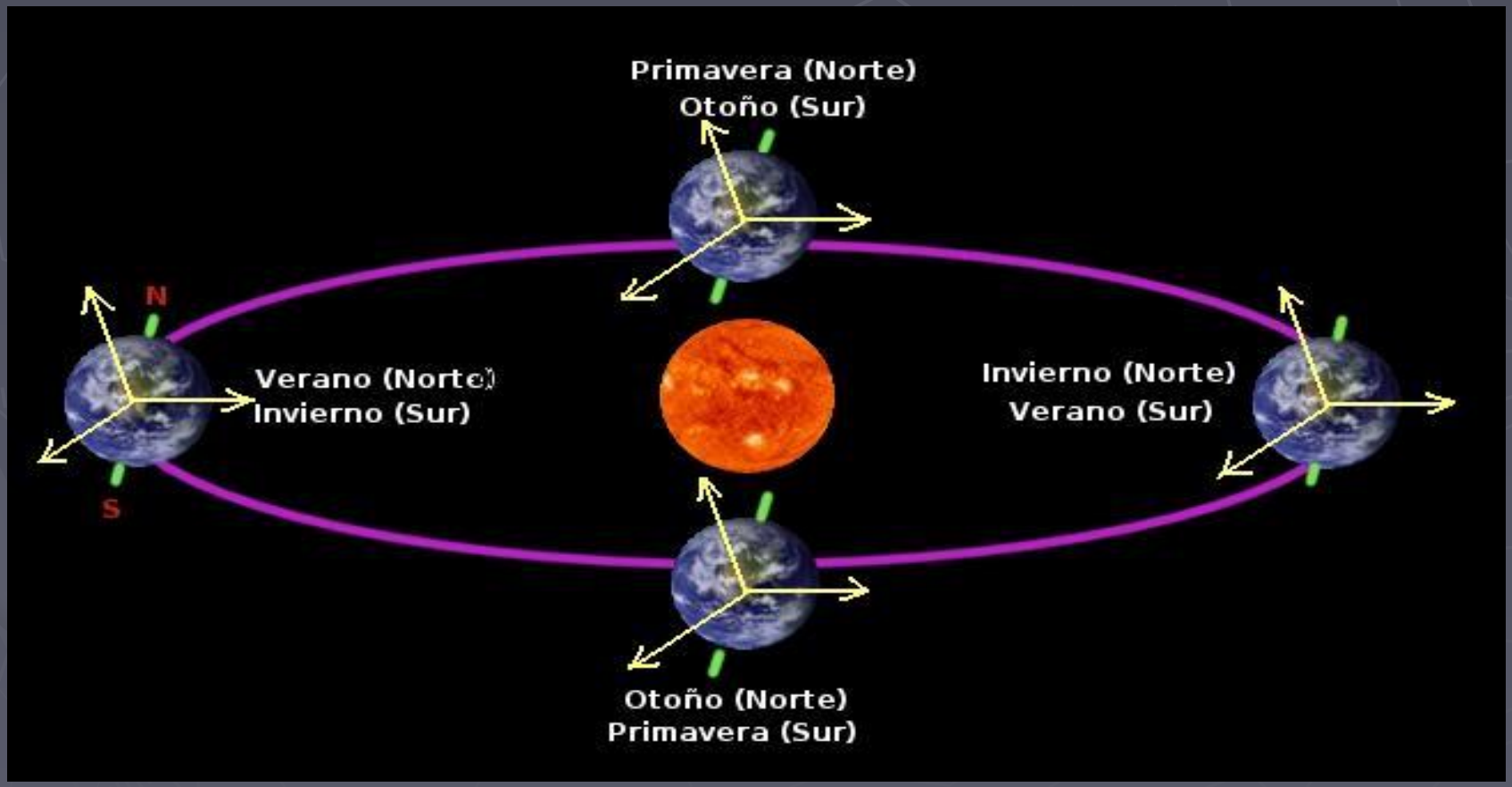
- **Reference Frame (RF) is the SR materialization. It is a group of element that determine accurately the SR and is constructed by the coordinates of the points of definition (observatories), applied techniques and methods of calculation**

In Astronomy, Geodesy and Geodynamics two fundamental RS and RF are necessary

CELESTIAL ⟷ **TERRESTRIAL**

Inertial Systems: A body persists in resting state or uniform rectilinear movement to unless an applicant force change their status

Quasi Inertial System: NO rotating system based on classical mechanics. Its origin can be accelerated



The Earth geocenter moves around an ellipse, while its axis is always parallel to themselves

Assembly Year 2000

International Geodesy and Geophysics Union (IGGU)
International Astronomical Union (IAU)

Modification of traditional and ancestral definitions from 01/01/2003

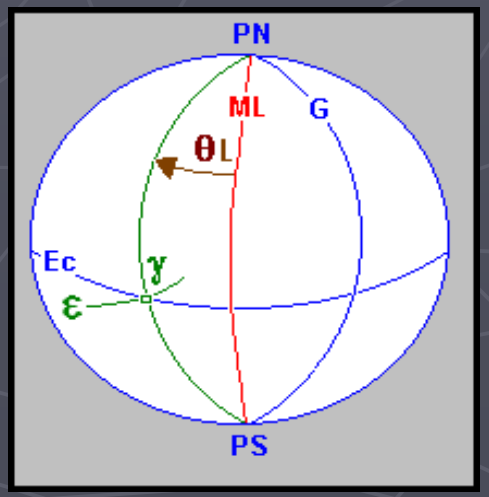
New definitions to Celestial and Terrestrial RS. An Intermediate System appears

New concepts

- Celestial Intermediate Pole (CIP)
- Changes in Precession-Nutation theory (PN)
- Celestial Intermediate Origin (CIO)
- Terrestrial Intermediate Origin (TIO)
- Earth Rotation Angle (ERA)

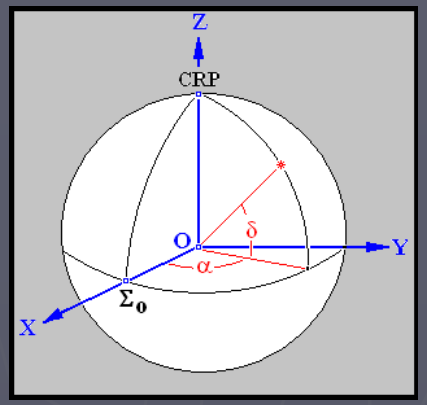
Obsoletes concepts

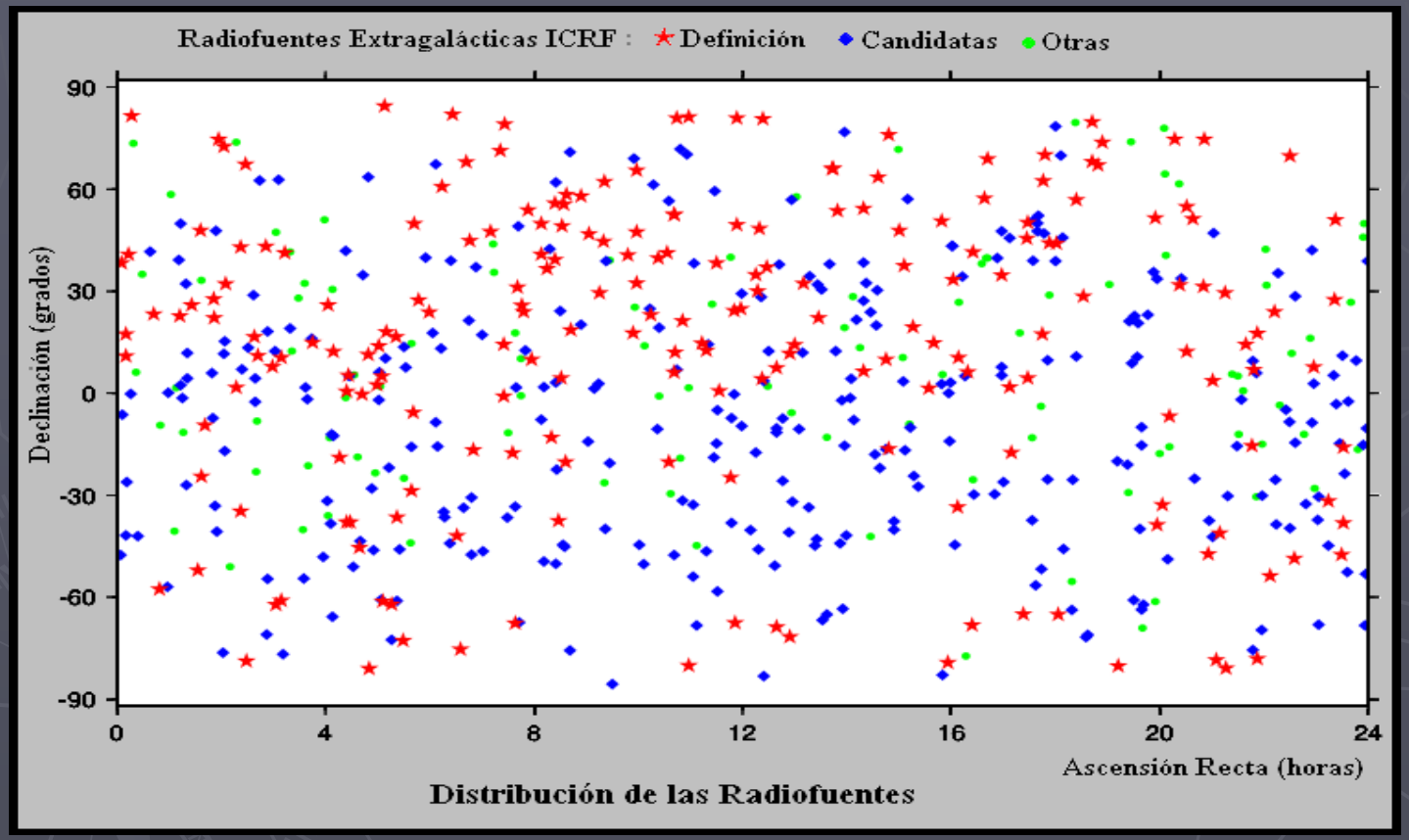
- Vernal Point or Equinox
- Ecliptical Plane
- Sideral Time
- Greenwich Meridian



RS → Celestial Baricentrical (BCRS)

RS → Celestial Geocentrical (GCRS)

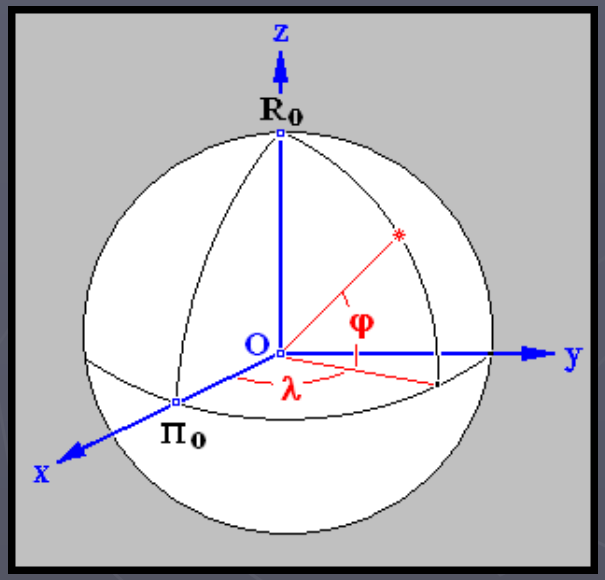




International Celestial Reference Frame (ICRF)

- Coordinates J2000.0 with VLBI of 900 Radio-sources IERS (more 300 definition)
- Mili arc second precision
- Origin Baricentric of the Solar System + General Relativity

International Terrestrial Reference System (ITRS)



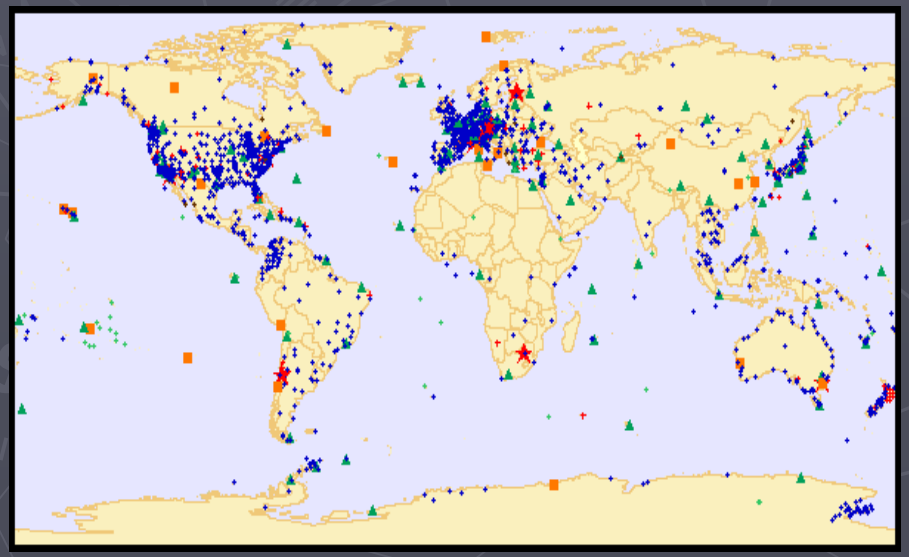
* Accompanies the rotation of the Earth

* Gives the position and velocity of a point on the surface

* The variations are due to geophysical causes

* The RF associated is formed by the coordinates geodesic Stationsl

International Terrestrial Reference Frame (ITRF)



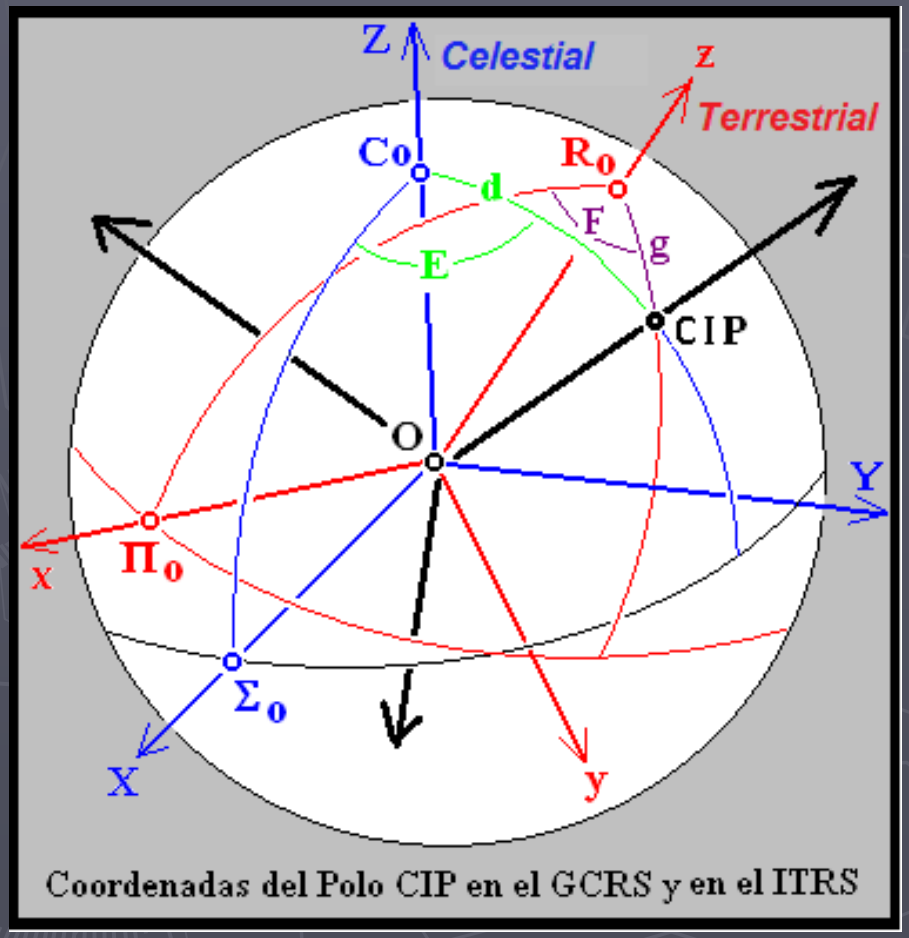
* Net Statios VLBI, LLR, SLR, GPS and Doris.

* Set of Coordinated and Velocity of IERS Stations (epoch ITRF yy)

* Each Station produces particular RF and IERS give the final ITRF

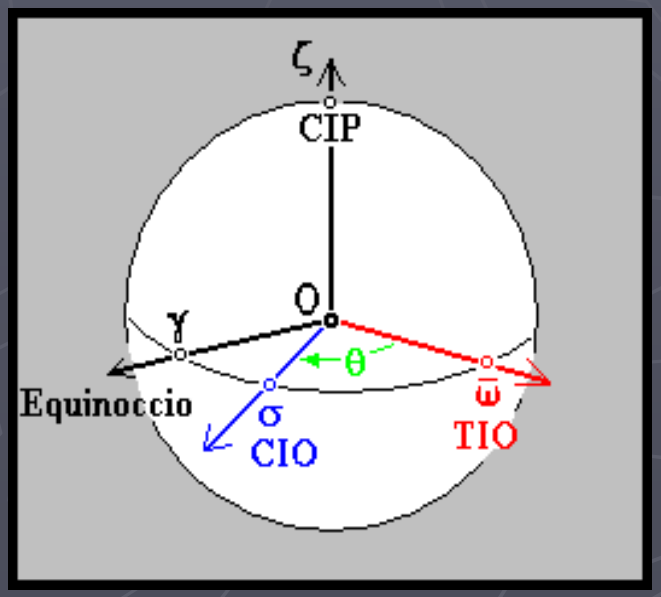
New Definitions to Origins

Celestial Intermediate Pole (CIP)



Assembly UAI 2000
From date 01/01/2003

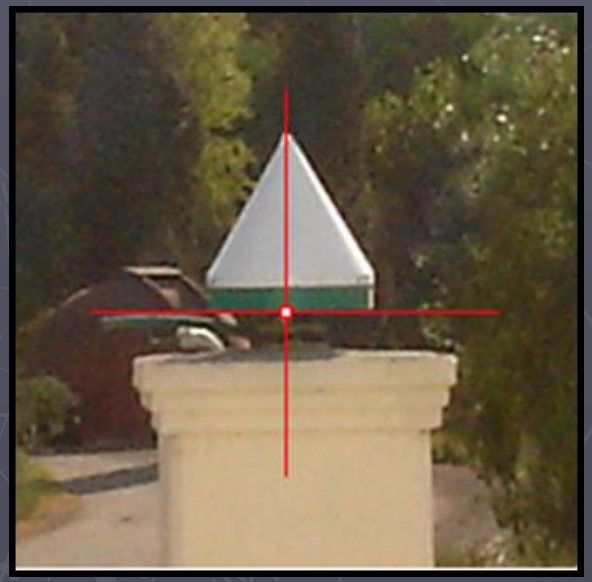
Celestial Intermediate Origin	(CIO)
Terrestrial Intermediate Origin	(TIO)



θ = arc $\varpi\,\sigma$

GPS Permanent Station

ASHTECH - Micro Z-CGRS



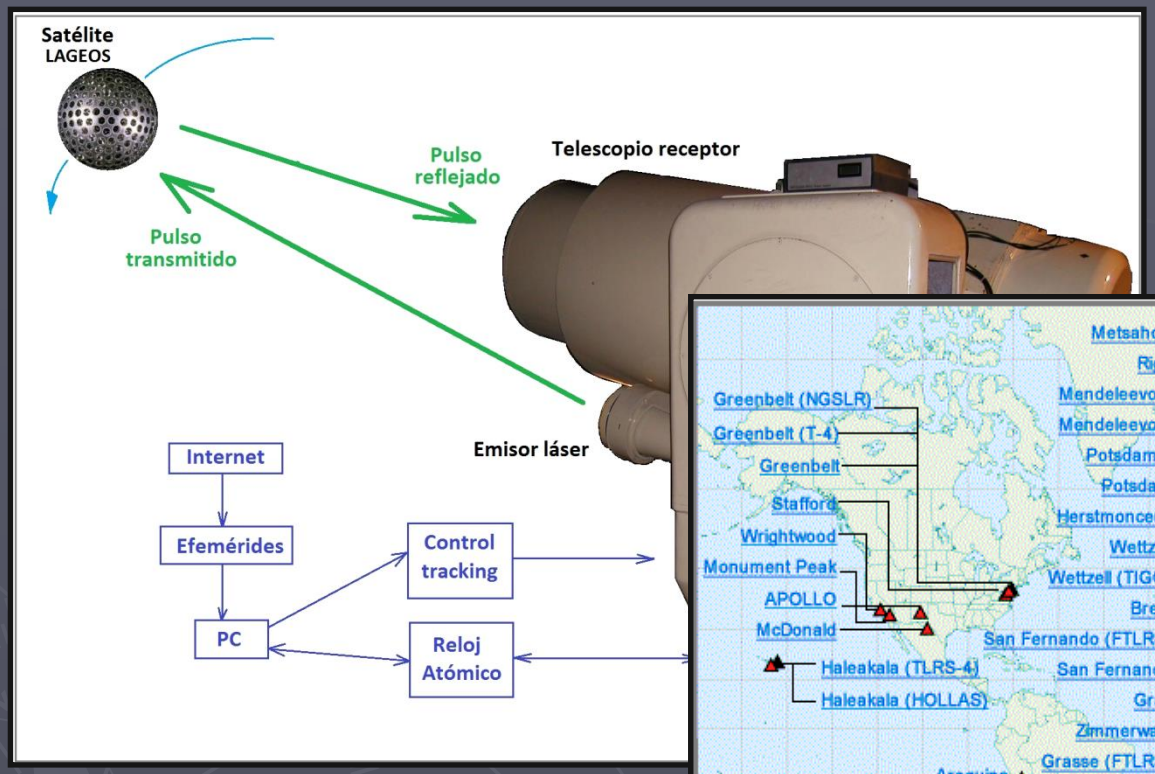
Reference point

Pillar with GPS antenna

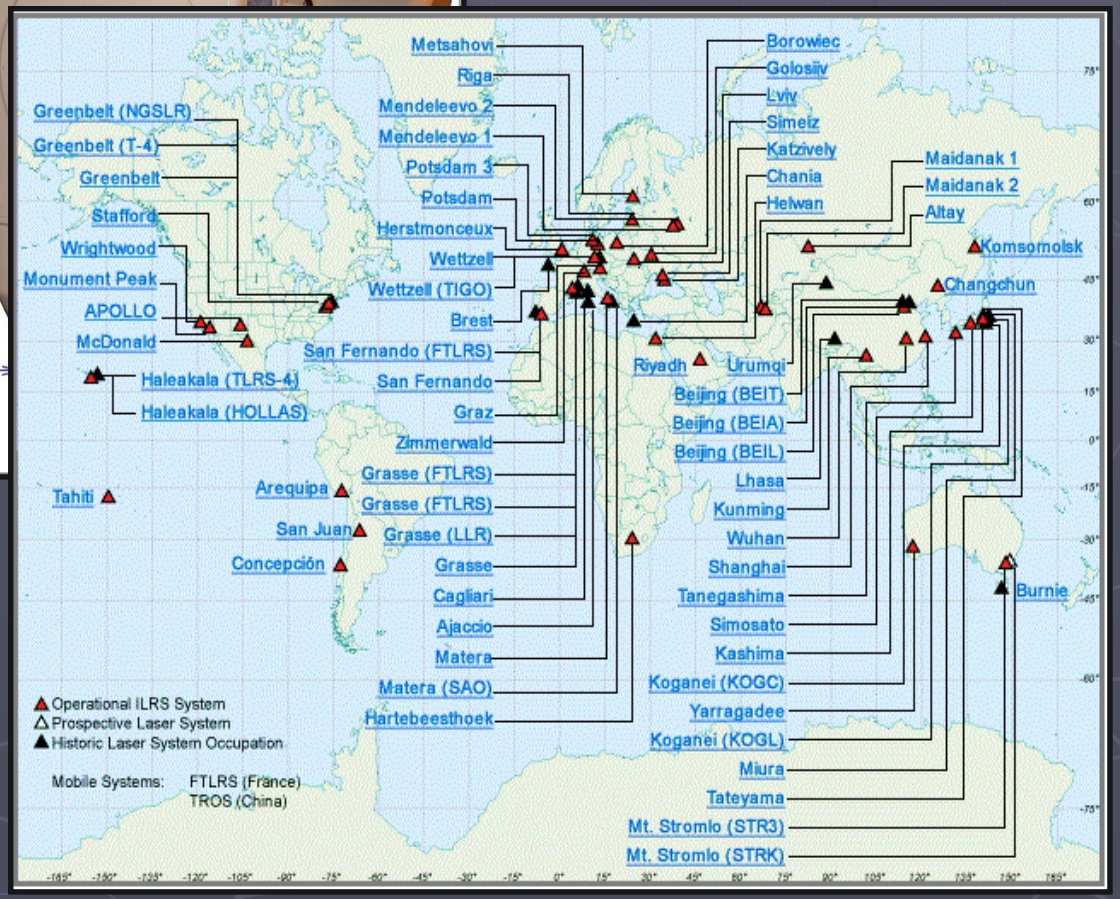
Edificio Walter T. Manrique

Punto de referencia

Satellite Laser Ranging (SLR)



Operating Scheme



ILRS Net Global

International Laser Ranging Service

SLR System in OAFA

Place

X = 1984104.114 m
Y = -5068867.289 m
Z = -3314482.433 m

L = -31°.5086249
B = -68°.6231602
H = 727.221 m

Cassegrain Telescope

Aperture 0.60 [*m*]

Mont AZ - EL

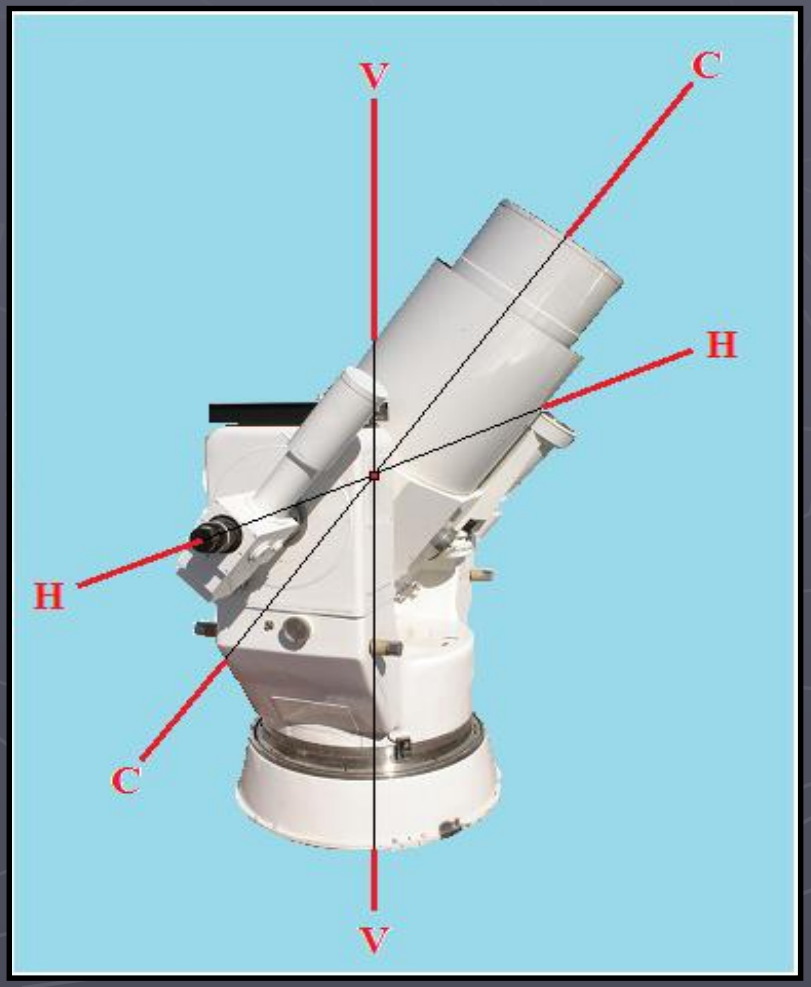
Oscillator Nd: YAG

Primary Wavelength 1064 [*nm*]

Máx. Energy 80 [*mJ*]

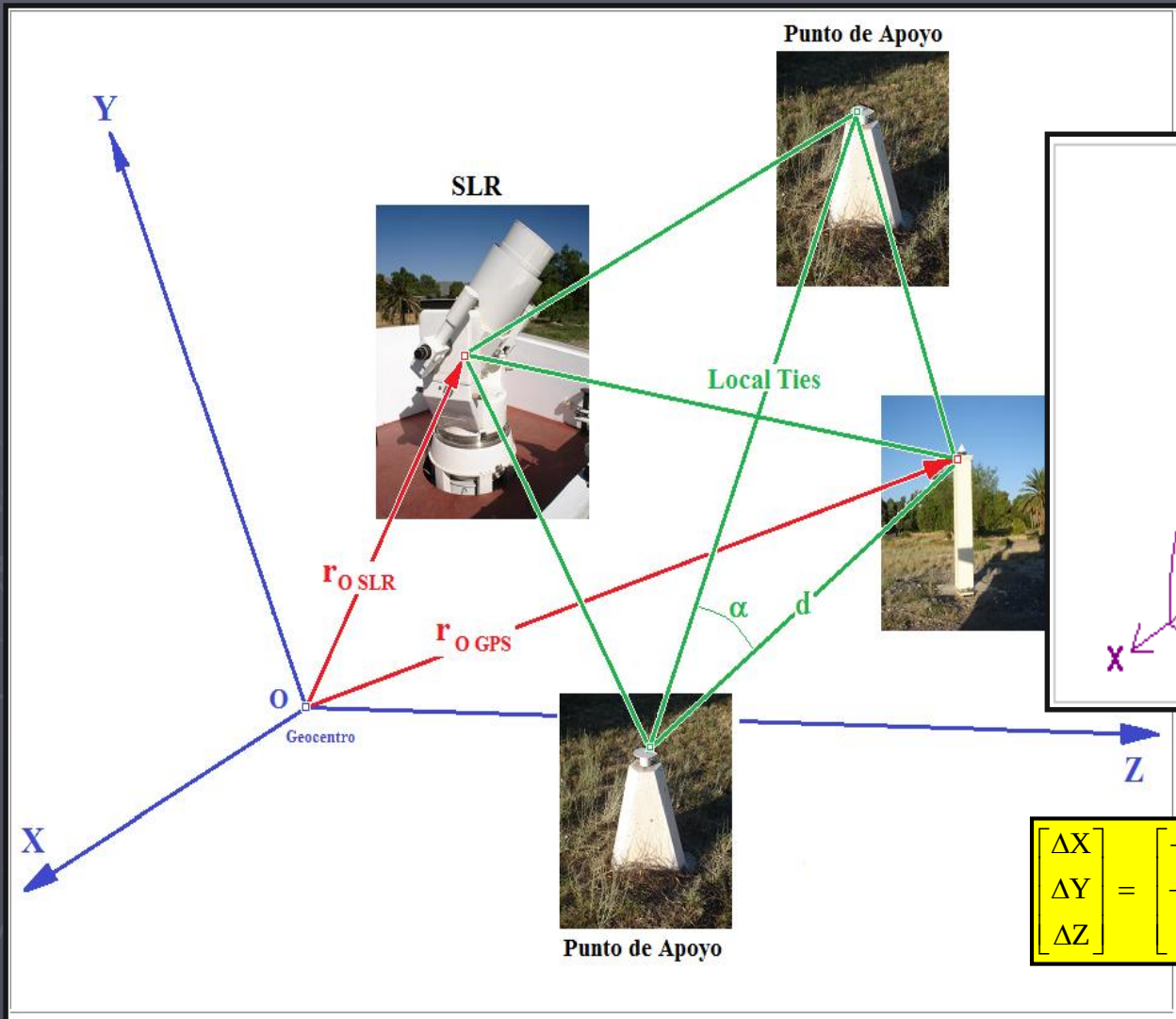
Secundary Wavelength 532 [*nm*]

Pulse width 30-50 [*ps*]

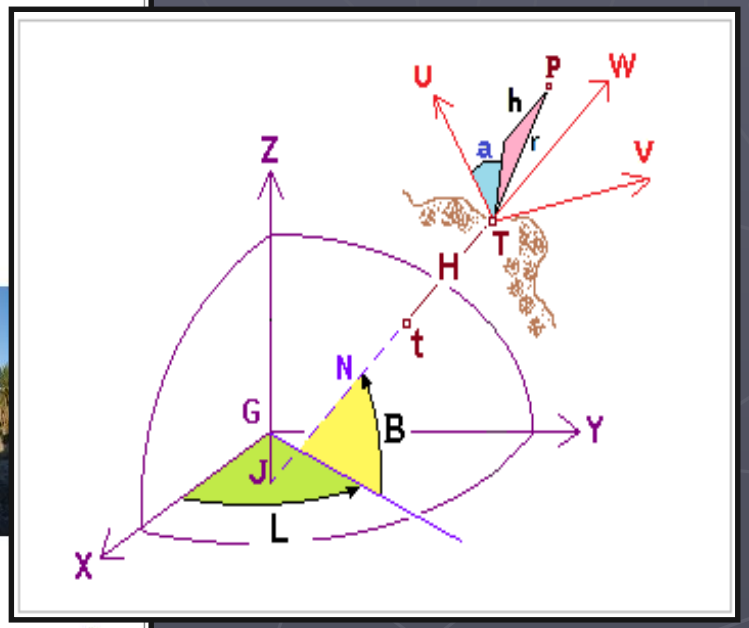


Co-locación Definition - *Local Ties LT*

Co-localization site is defined by two or more space geodetic techniques occupying nearby, linked to each other with very precise measurements in 3D



Geodesic Net

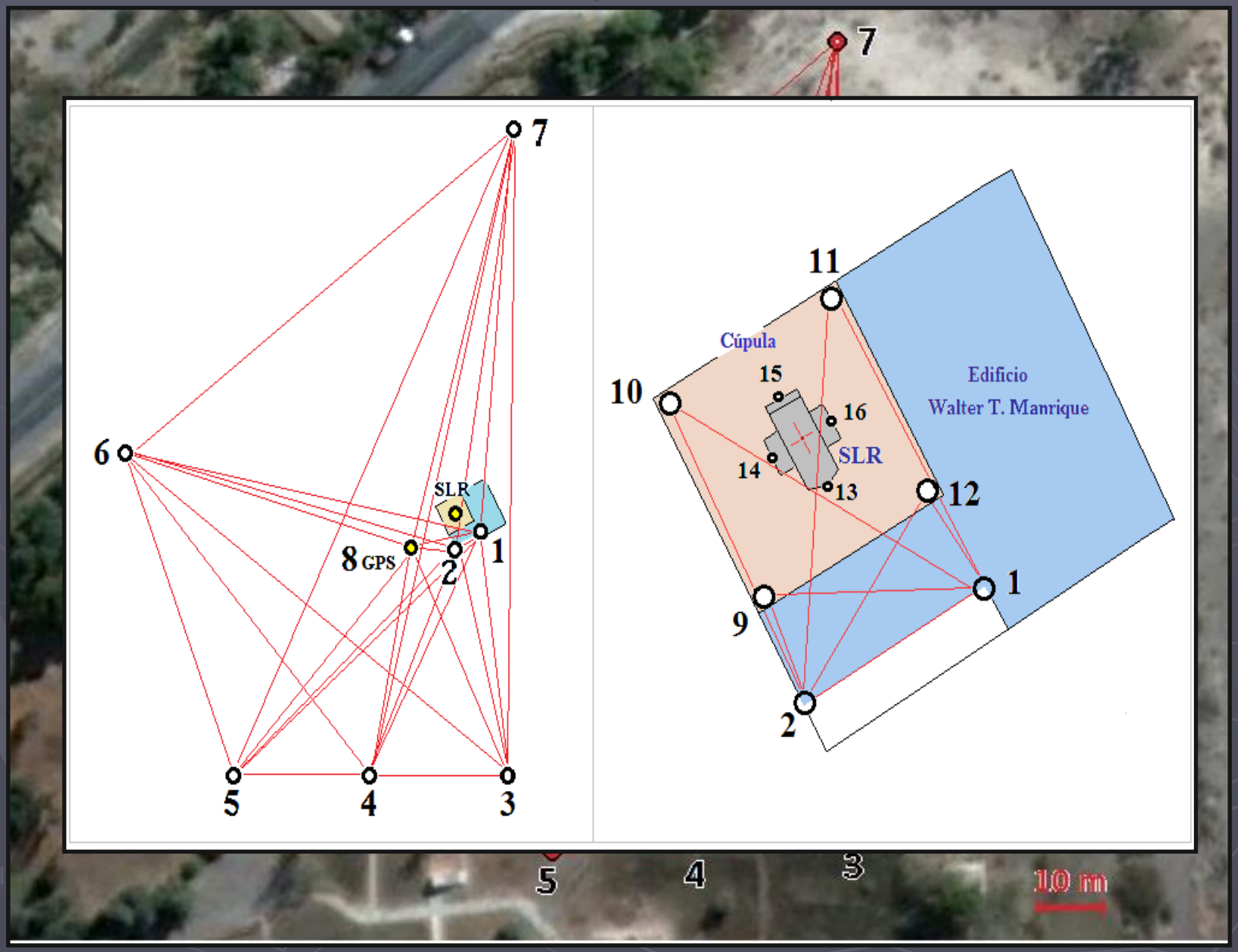


$$\begin{bmatrix} \Delta X \\ \Delta Y \\ \Delta Z \end{bmatrix} = \begin{bmatrix} -\,sen\,B\ \cos L & -\,sen\,L & \cos B\ \cos L \\ -\,sen\,B\ sen\,L & \cos L & \cos B\ sen\,L \\ \cos B & 0 & sen\,B \end{bmatrix} \begin{bmatrix} \Delta U \\ \Delta V \\ \Delta W \end{bmatrix}$$

GPS GTR-A

GPS geodésic TRIMBLE

Geodesy Net


7
6
SLR
8 GPS
2
1
5
4
3
11
Cúpula
15
10
16
Edificio
Walter T. Manrique
SLR
14
13
12
1
9
2
10 m

Set up of the reference points

Point 7

Point 3

Points 1 y 2

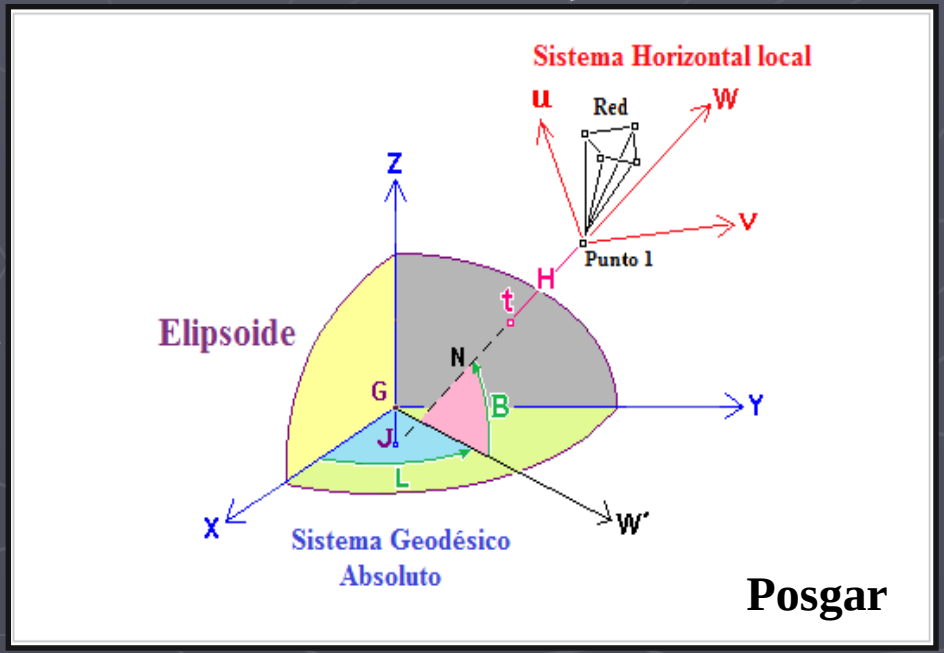
Metodology

Tradicional Net in a local system

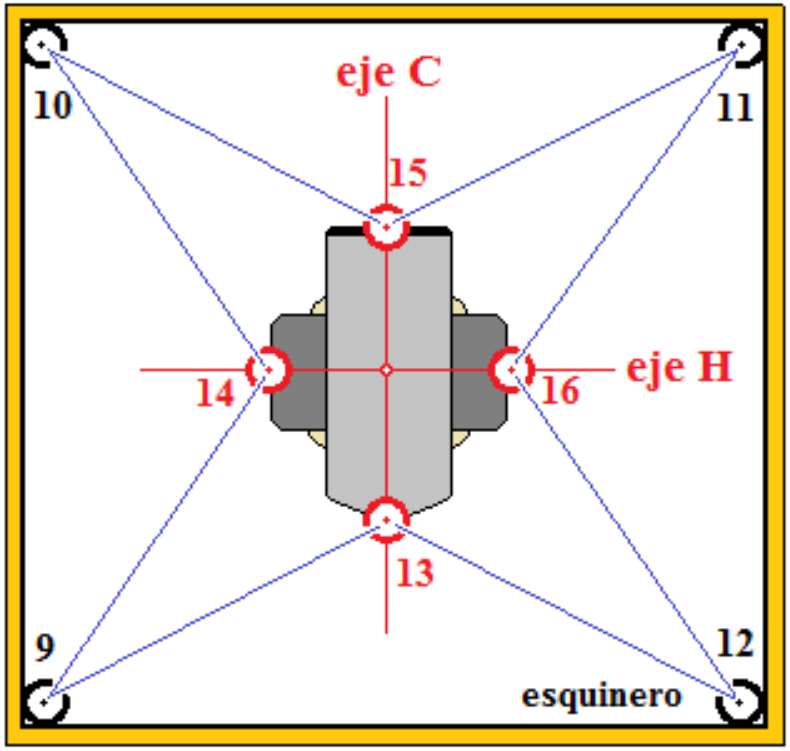
GPS Net in a local system

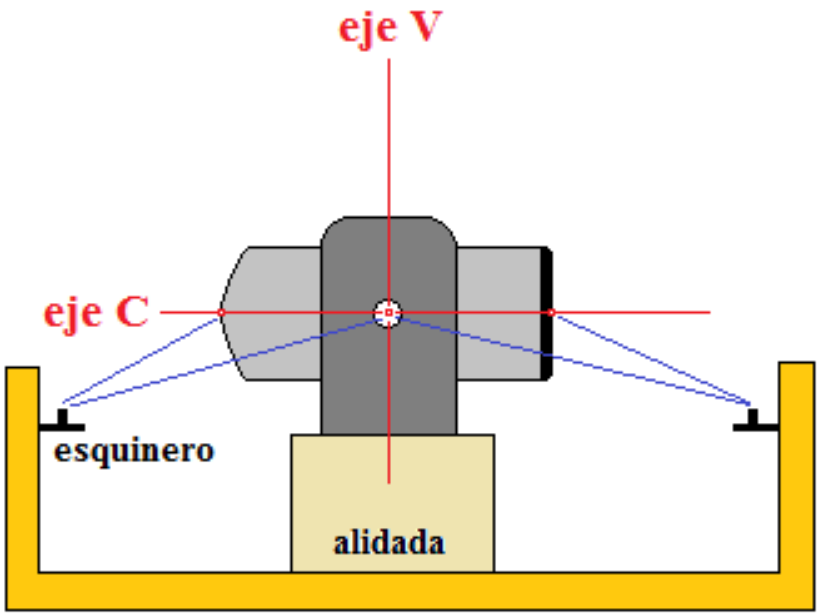
Measure of angles and distancess Trilateration and Leveling

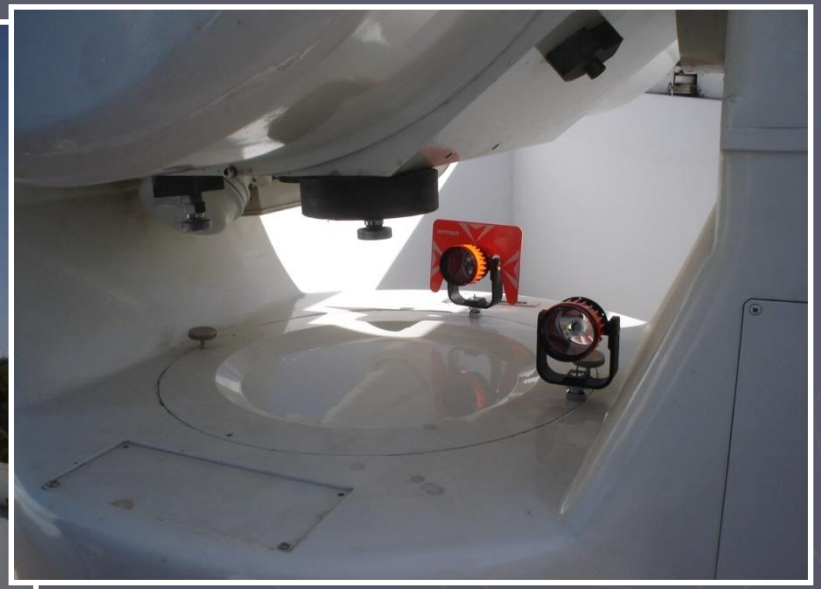
Vectors determination



Posgar


eje C
10
11
15
14
16
eje H
13
9
12
esquinero


eje V
eje C
esquinero
alidada



Calculation and compensation

Output file REDGPS_ALV with the matrix Variance – Covarianceof the observed vectors components

Matriz OGPS
Punto Origen / Punto Extremo / dx / dy / dz

6.0000	5.0000	2.2740	31.6120	-45.3680
6.0000	7.0000	79.4790	-17.6240	73.6150
6.0000	7.0000	79.4770	-17.6300	73.6190
6.0000	3.0000	46.9970	49.0400	-45.2550
5.0000	7.0000	77.2050	-49.2340	118.9810
5.0000	3.0000	44.7260	17.4260	0.1130

……
…..

Punto Origen-Punto Extremo
1.0e-004 *

6-5

0.1330	0	0
-0.0770	0.3150	0
0.0043	0.0061	0.0963

6-7

0.1820	0	0
-0.1070	0.2980	0
-0.0127	0.0077	0.0920

6-3

0.2280	0	0
-0.1290	0.5730	0
0.0066	0.0129	0.1680

…

PASA EL TEST CHI CUADRADO AL 95%

COORDENADAS AJUSTADAS

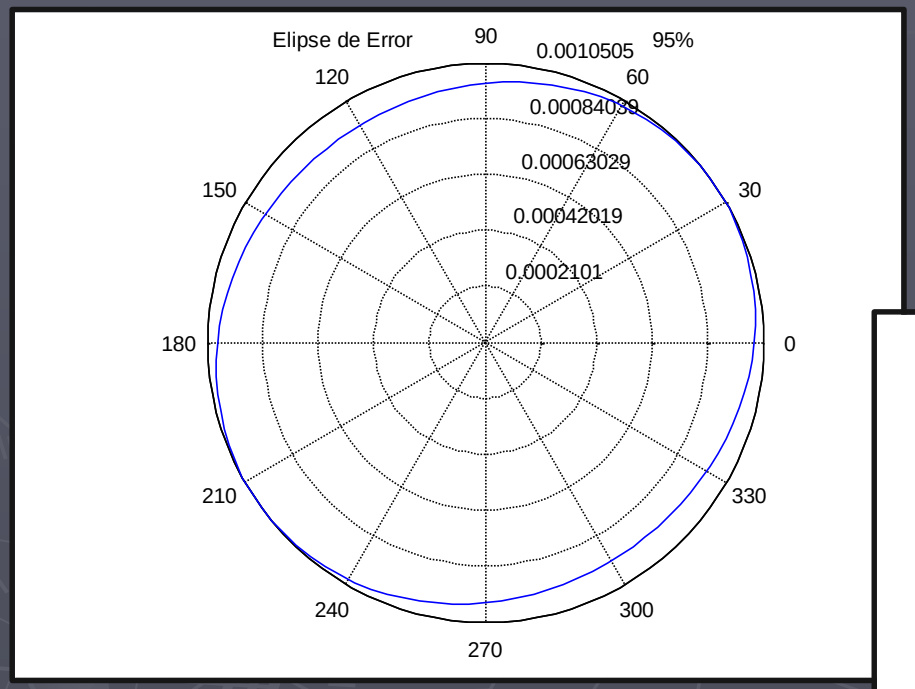
PUNTO	X	Y	Z
1.00	1984110.41	-5068864.32	-3314482.44
2.00	1984106.39	-5068864.51	-3314484.58
3.00	1984100.26	-5068831.66	-3314531.04
4.00	1984077.89	-5068840.38	-3314531.10
5.00	1984055.53	-5068849.09	-3314531.15
6.00	1984053.25	-5068880.70	-3314485.78
7.00	1984132.73	-5068898.33	-3314412.17
8.00	1984095.78	-5068868.33	-3314485.50

ERRORES ESTANDAR DE LAS COORDENADAS AJUSTADAS

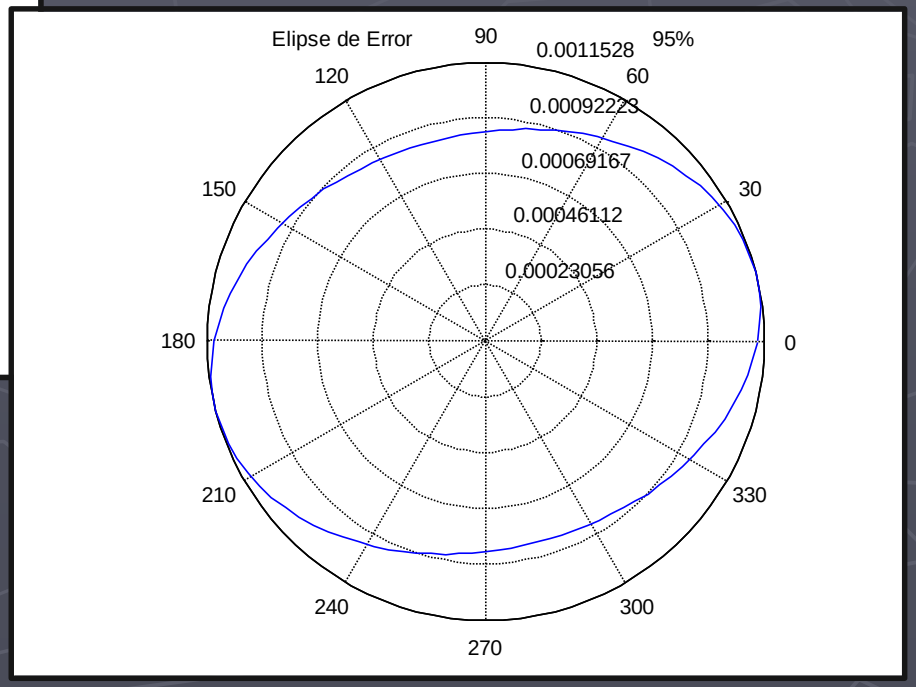
PUNTO	ERRX.	ERRY.	ERRZ.	EERM(est.)
1.0000	0.0005	0.0007	0.0005	0.0009
2.0000	0.0006	0.0008	0.0007	0.0012
3.0000	0.0005	0.0007	0.0005	0.0010
4.0000	0.0005	0.0007	0.0005	0.0010
5.0000	0.0005	0.0006	0.0005	0.0009
6.0000	0.0005	0.0007	0.0005	0.0010
7.0000	0.0005	0.0007	0.0004	0.0009
8.0000	0.0004	0.0006	0.0004	0.0009

Error Ellipses

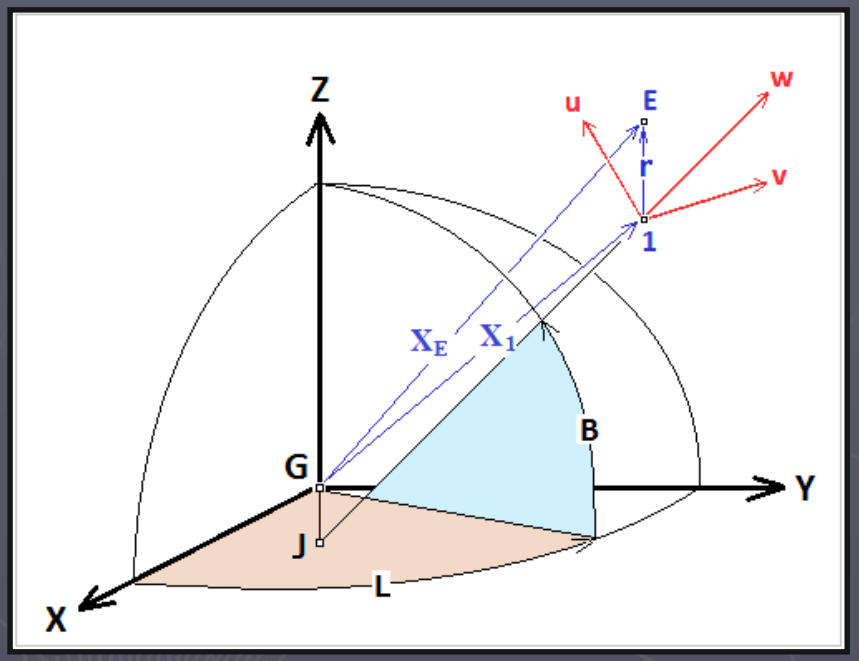
***ELIPSE PUNTO* 1**
***SEMIEJE MAYOR A=0.0011 m ,**
***SEMIEJE MENOR B=0.0009 m**
***AZIMUT FI=34.83 grados ,**
***EXCENT. =0.1881 , *AREA (cm2) = 0.03**



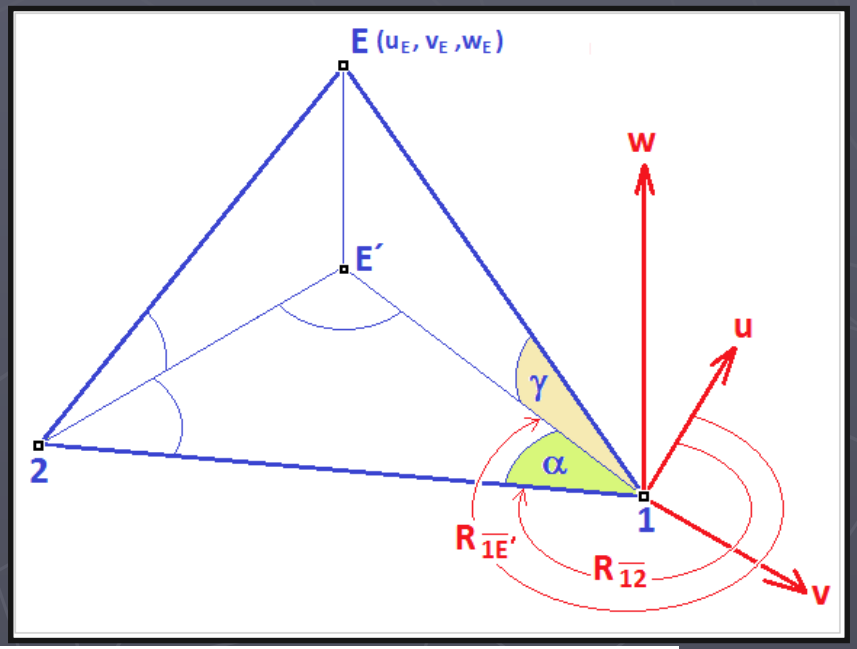
***ELIPSE PUNTO* 7**
***SEMIEJE MAYOR A=0.0012 m ,**
***SEMIEJE MENOR B=0.0009 m**
***AZIMUT FI=14.54 grados ,**
***EXCENT. =0.4456 , *AREA (cm2) = 0.03**



Error propagation



Based on the local system centered on the vertex 1 of the geodetic network, errors propagated by the linear and angular measurements cornerbacks points are determined by the formulas:



$$\sigma_{w_E} = \sqrt{\left(\frac{\partial f}{\partial \overline{1E}}\right)^2 \sigma^2_{\overline{1E}} + \left(\frac{\partial f}{\partial \gamma}\right)^2 \frac{\sigma^2_{\gamma}}{206265^2}}$$

$$\sigma_{u_E} = \sqrt{\left(\frac{\partial f}{\partial \overline{1E}}\right)^2 \sigma^2_{\overline{1E}} + \left(\frac{\partial f}{\partial \alpha}\right)^2 \frac{\sigma^2_{\alpha}}{206265^2} + \left(\frac{\partial f}{\partial \gamma}\right)^2 \frac{\sigma^2_{\gamma}}{206265^2} + \left(\frac{\partial f}{\partial R_{\overline{12}}}\right)^2 \frac{\sigma^2_{R_{\overline{12}}}}{206265^2}}$$

$$\sigma_{v_E} = \sqrt{\left(\frac{\partial f}{\partial \overline{1E}}\right)^2 \sigma^2_{\overline{1E}} + \left(\frac{\partial f}{\partial \alpha}\right)^2 \frac{\sigma^2_{\alpha}}{206265^2} + \left(\frac{\partial f}{\partial \gamma}\right)^2 \frac{\sigma^2_{\gamma}}{206265^2} + \left(\frac{\partial f}{\partial R_{\overline{12}}}\right)^2 \frac{\sigma^2_{R_{\overline{12}}}}{206265^2}}$$

Final coordinates of the network points

Posgar 2007, epoch June 26/2012 (2012.403).

Punto	X	Y	Z
1	1984110,4081	-5068864,3161	-3314482,4443
2	1984106,3887	-5068864,5135	-3314484,5838
3	1984100,2568	-5068831,6577	-3314531,0416
4	1984077,8903	-5068840,3763	-3314531,1024
5	1984055,5276	-5068849,0898	-3314531,1517
6	1984053,2547	-5068880,6993	-3314485,7836
7	1984132,7308	-5068898,3303	-3314412,1670
8	1984095,7826	-5068868,3277	-3314485,5004
9	1984105,4952	-5068866,0664	-3314482,3068
10	1984104,1382	-5068868,7369	-3314479,3020
11	1984107,6748	-5068868,1806	-3314477,1238
12	1984109,0978	-5068865,6022	-3314480,1866
CGL	1984106,7928	-5068867,4829	-3314479,9346

$$\text{Vector Punto 8 - CGL} = \sqrt{(X_8 - X_{CGL})^2 + (Y_8 - Y_{CGL})^2 + (Z_8 - Z_{CGL})^2} = 12.3659 \text{ metros}$$

Standard errors of the adjusted coordinates (meters)

Punto	sX	sY	sZ
1	0,0005	0,0007	0,0005
2	0,0006	0,0008	0,0007
3	0,0005	0,0007	0,0005
4	0,0005	0,0007	0,0005
5	0,0005	0,0006	0,0005
6	0,0005	0,0007	0,0005
7	0,0005	0,0007	0,0004
8	0,0004	0,0006	0,0004
9	0,0015	0,0011	0,0023
10	0,0014	0,0016	0,0022
11	0,0010	0,0024	0,0016
12	0,0011	0,0023	0,0016
CGL	0,0010	0,0031	0,0014

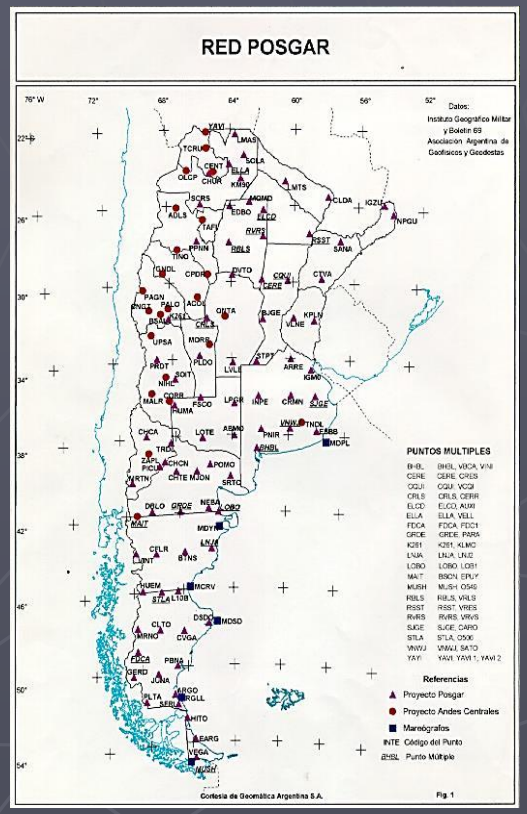
Conclusions

Space geodetic techniques are only used in the development of frameworks.

Addition to the primary core ITRF observation stations, the global network is densified with regional GPS subnets. In America and in Argentina densification SIRGAS and POSGAR have positions within the centimeter accuracies and speeds of the order of 1.5 mm / year.

A station acquires status station co-located, you can integrate these networks as a reference of the first order

SIRGAS-CON



The network designed did not consider the location of any point east of the building Walter Manrique. Despite this adjustment was excellent but, in order to provide the network with greater strength, it would be advantageous densify with a vertex to the east with direct visibility point 1.

Due to the impossibility of view between the terrestrial network points and mount SLR, we had to designing a particular methodology for connection

Obviously there are propagation of errors in the coordinates due to linear and angular measurements taken.
The average standard deviations in all three axes increased from external points (1 to 8) to internal (9 to CGL); but everything indicates that worked very carefully, because the resulting error in determining the CGL is within the requirements of the IERS.

The standard deviations of the rectangular geodetic coordinates obtained in the adjustment of all network points were within 3 mm, excelling value that will enable the OAFA to be considered by the IERS as a co-located station.

MUCHAS GRACIAS