Local ties to determine the co-location vector from the SLR telescope and GPS antenna in San Juan, Argentina

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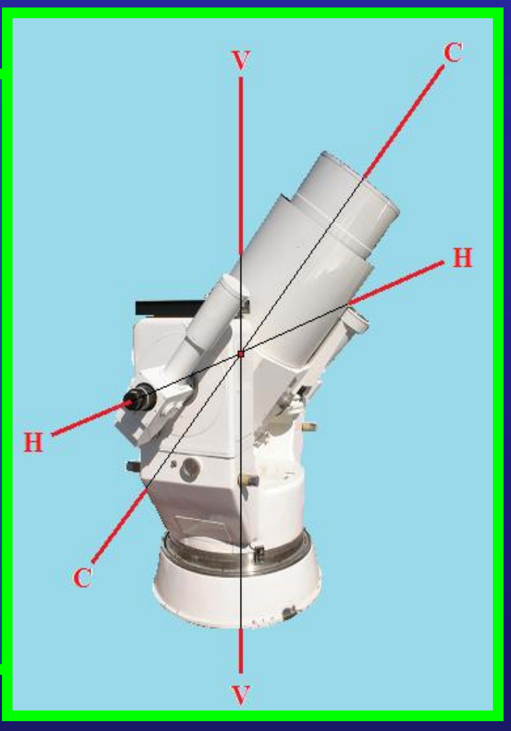
San Juan SLR Station ILRS 7406

GPS ASHTECH Micro Z

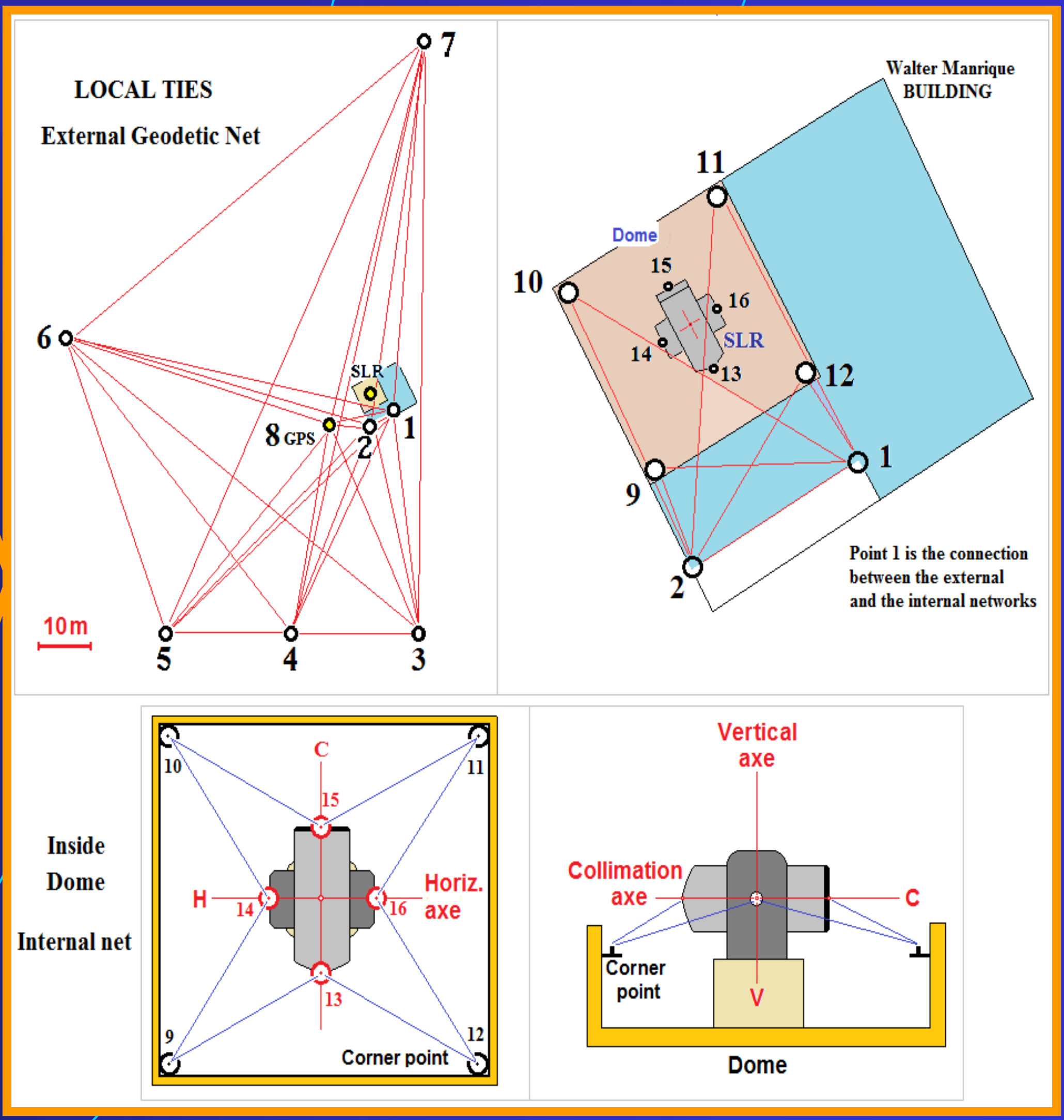
We presents the theoretical and practical fundamentals employed to conjointly co-locate the Chinese Satellite Laser Ranging ILRS 7406 telescope and the antenna of the permanent station GPS, both installed at the site of the Félix Aguilar Astronomical Observatory in San Juan, Argentina (OAFA). The principal objective was to establish a local ties geodesic grid with support points distributed about both instruments and to determine their rectangular geodesic coordinates and the vector that unites their geometric centers [1].

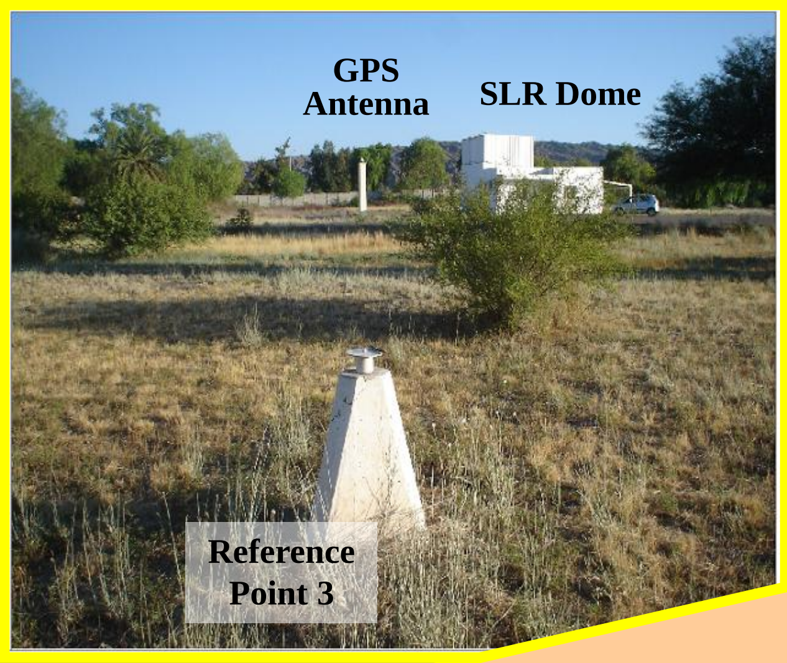
Because the geometric or optical telescope SLR center defined by the intersection of their rotational axes horizontal (HH), vertical (VV) and collimation (CC), are located inside the apparatus, this point is not accessible and available for direct measurements.

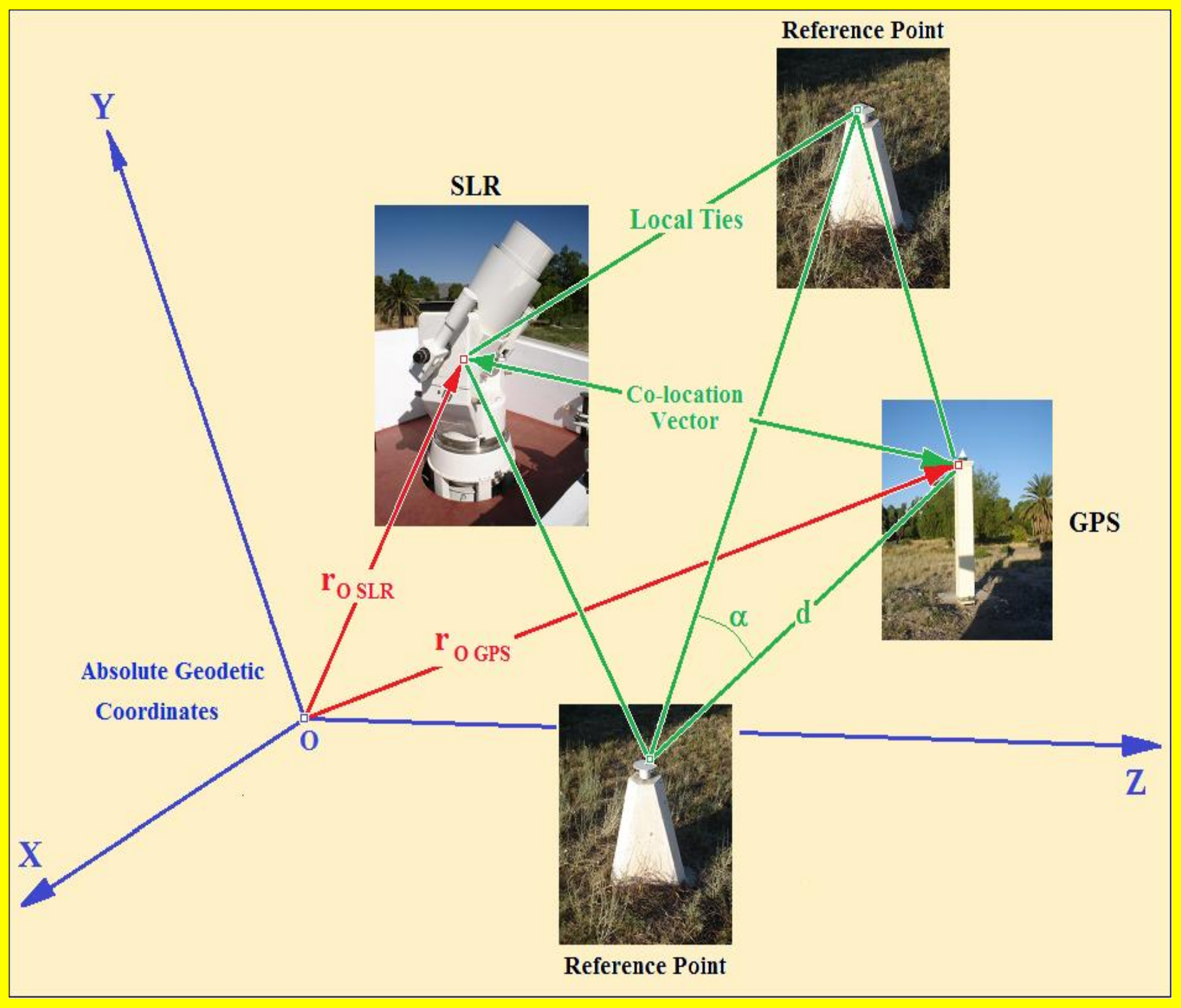
Therefore is required to employ an appropriate methodology for mathematically determination the exact position of the center, which is a demanding task that requires very careful techniques and the best measurement tools



The laser telescope of OAFA is mounted into a dome constructed in such a manner that the mounting itself is occulted from ground level. For this reason it was necessary to develop a particular methodology to determine and link its optical center, using an special supporting geodesic grid.







Materializing the axes

LOCAL NETWORK

To achieve the accuracy required by the ITRF in determining Local Ties was designed with own software, a network of points with external forced centering near the GPS and SLR, to no more than 80 meters away (points 3, 4, 5, 6, 7) and a subnet of internal points within the building SLR dome (dome points 1, 2, 9, 10, 11, 12) to measure over the structure of the telescope SLR.

Instruments Pentax Total Station V200, Wild T3 Theodolite, Level Boif, GPS Trimble, GPS GTRA and mirrors were used.

Point 1 was considered the main station link between the external and the internal network, that allowed the determination of the optical center of the SLR. To determine the Local Ties in three dimensions, measurement techniques such as triangulation, trilateration, leveling and GPS were used

Point	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 GPS Antenna	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
Optical Center SLR	1984106,7928	-5068867,4829	-3314479,9346

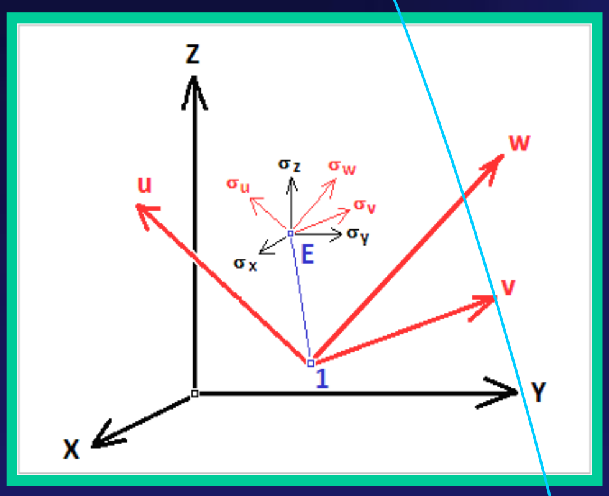
Point	σX	σY	σZ
1	0,0005	0,0007	0,0005
2	0,0006	0,0008	0,0007
3	0,0005	0,0007	0,0005
4	0,0005	0,0007	0,0005
5	0,0005	0,0006	0,0005
6	0,0005	0,0007	0,0005
7	0,0005	0,0007	0,0004
GPS Antenna	0,0004	0,0006	0,0004
9	0,0015	0,0011	0,0023
10	0,0014	0,0016	0,0022
11	0,0010	0,0024	0,0016
12	0,0011	0,0023	0,0016
Optical Center SLR	0,0010	0,0031	0,0014

$$\text{Co-location Vector: Point 8 (Antenna) - SLR} = \sqrt{(X_8 - X_{SLR})^2 + (Y_8 - Y_{SLR})^2 + (Z_8 - Z_{SLR})^2} = 12.3659 \text{ meters}$$

Reference Frame : ITRF 2005

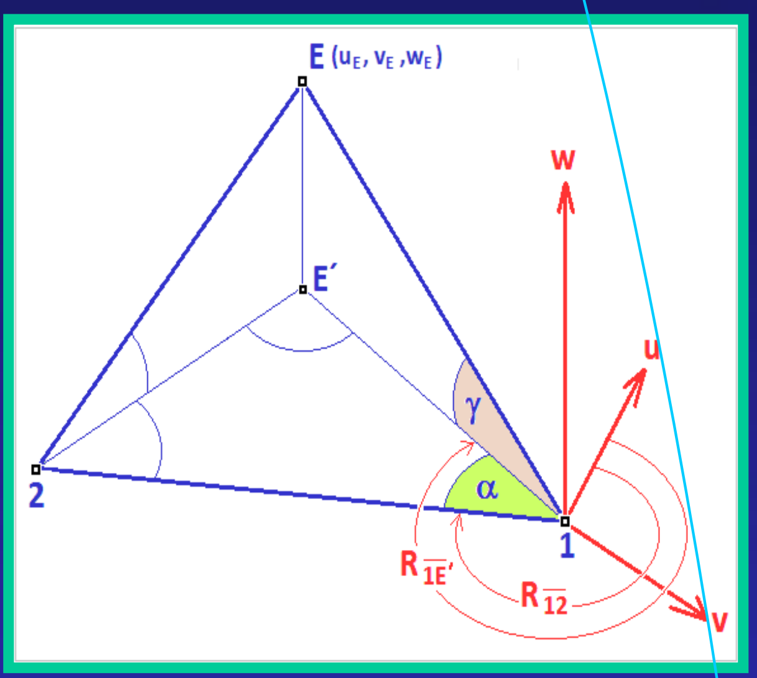
Epoch : 2012.403

Error Propagation



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

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



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

$$\frac{\partial f}{\partial \overline{1E}} = \cos\gamma \ \cos(R_{\overline{12}} \pm \alpha)$$
$$\frac{\partial f}{\partial \alpha} = -\overline{1E} \ \cos\gamma \ \operatorname{sen}(R_{\overline{12}} \pm \alpha)$$
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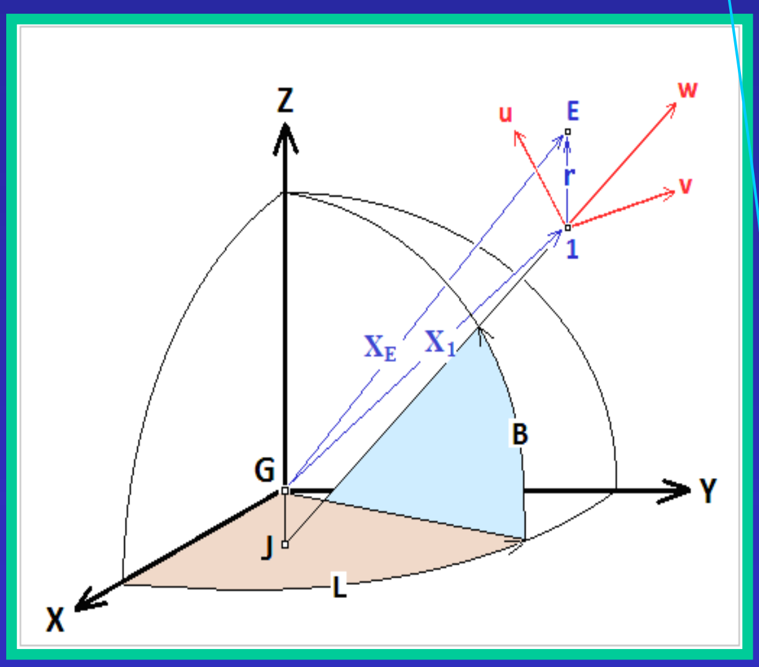

Absolute geodetic coordinates

The greatest impact on error propagation occurs in the angular measurements, depending largely on the quality of the optical instrument used. We use a Pentax Total Station V200 with an accuracy of 7 ", which is good, but there are much better instruments with an accuracy of 1" not available right now. The obtained values of the standard deviations of the geodetic network are within recommended by the IERS (about 3 mm). This shows that the design, measurement and adjustment of the network have been a very satisfying job.

- **The main objective of this work was to form a geodetic network with distributed reference support points around the GPS antenna and SLR telescope, find geodesic rectangular coordinates and determine the vector linking their geometrical centers with the best possible accuracy.**
- **This is the first time that a study of this nature has been performed in Argentina and its goals have been met. The precision achieved in the determination of the instrumental optical centre and the measurement uncertainties are within the maximum tolerance errors (3 mm) stipulated by the IERS for works like this one [2].**

References: [1] Altamini Z. (2003) ITRF and Co-location Sites. ENSG / LAREG, France. IERS Tech. Notes Nº 33
[2] Thaller D. et al. (2011) Combination of GNSS and SLR observations using satellite co-locations