PRACTICALITIES OF LOCAL TIES AND SLR CALIBRATION

John McK. LUCK,
EOS Space Systems Pty.Ltd.,
Canberra, Australia
jmckluck@optusnet.com.au

ABSTRACT

- The geometric relationships between the instrumental reference points of space geodetic instruments situated in close proximity to each other, and between them and ground monumentation, need to be determined with high accuracy to achieve proper combinations of the various techniques and to monitor the stability of the points. The methods and results of repeated local tie surveys at several prime stations will be described, primarily at Mount Stromlo, Australia where SLR, DORIS, GPS and GLONASS instruments and fiducial pillars are connected with formal RMSs less than 1 mm and similar two-year repeatabilities.
- These surveys also include the calibration target mirrors used routinely to measure the system delay in SLR stations. Four such external targets at Stromlo provide a very convenient way to monitor overall system and site stability. Other stations use variants of this scheme to ensure that their systems are calibrated as well as possible.

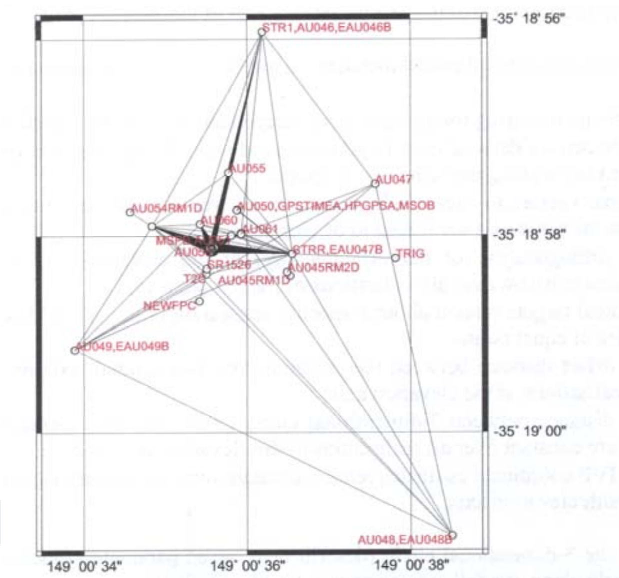
MOUNT STROMLO SLR STATION

DORIS SLR METS (DIMM) NEW GPS GPS & CAL (NORTH PIER)

27 May 2004

STROMLO LOCAL TIE NETWORK

AU046 (NORTH PIER)

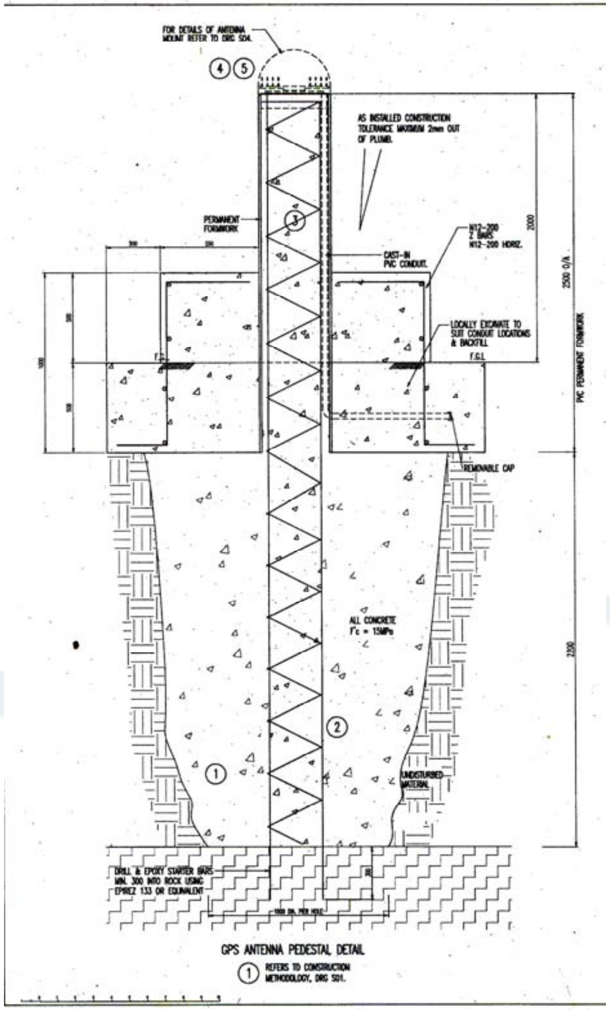


2" in latitude = 62 metres

FIG 1: 4 SLR CAL TARGETS ARE AT THE OUTERMOST VERTICES

NORTH PIER WITH GPS ANTENNA AND SLR CAL TARGET

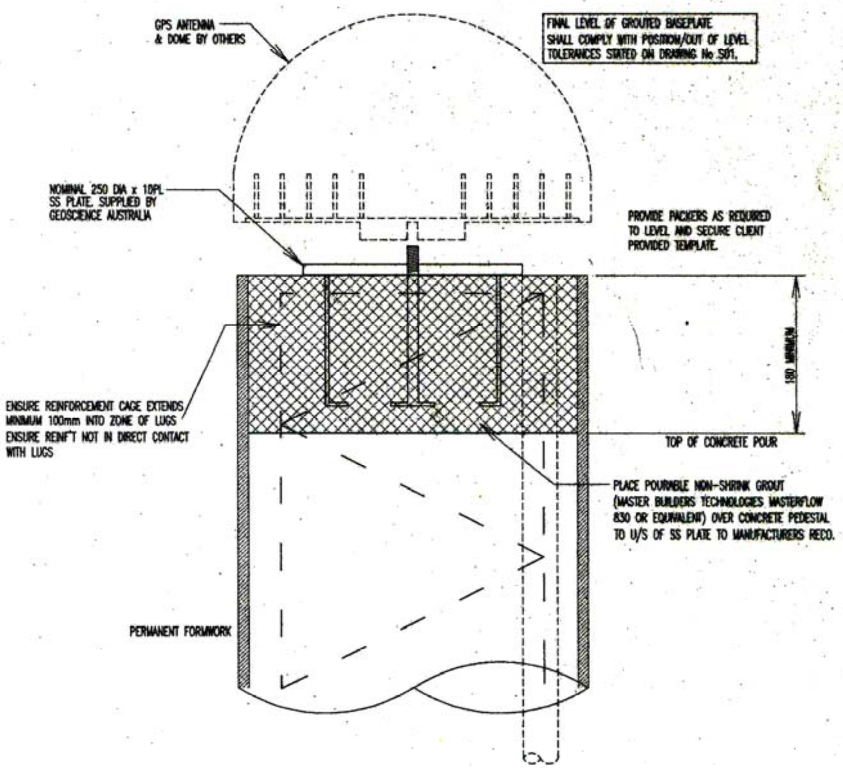
MONUMENT CONSTRUCTION



FIDUCIAL MONUMENT – NOTE MASSIVE BASE

27 May 2004

TOP OF NEW MONUMENT BEING ADDED TO NETWORK, SUPPORTING GPS ANTENNA



GPS ANTENNA MOUNT SECTIONAL VIEW

PLANNING AND STRATEGIES FOR LOCAL TIE SURVEYS

- Be timed for optimum survey observations, i.e. timing the survey when weather conditions are neutral to minimise atmospheric effects;
- Allow for several days down time, particularly on Satellite Laser Ranging (SLR) or Very Long Baseline Interferometry (VLBI) systems;
- Be planned to avoid critical tracking campaigns;
- Plan the placement of marks on the telescope/antenna to optimise observations for the determination of axes (in the case of indirect reference point determination), i.e. optimise the target trajectories and the radius of the trajectories; and
- Place instrument stand-points to satisfy survey accuracy demands (as determined by network simulation if necessary).
- Forced centring is used to eliminate the introduction of setup errors wherever possible. A Leica Zenith Nadir precise optical plummet is used for all tripod setups, to ensure near zero plumbing errors. Additionally, wherever possible concrete pillars are used for instrument standpoints. This ensures setup stability during the often long observation periods when observations are taken to the antenna or telescope systems.

SURVEYING EQUIPMENT AND THEIR CALIBRATION

- Leica TCA 2003 Total Station
- Angular Precision (lab. calibrated) 0.”6
- Distance Precision (lab.calibrated) 0.5mm + 0.4ppm
- Annually compared with standard baseline traceable to Aust’n National Standards
- Leica precision prisms with tribrach and carriers incl. plate bubble
- Annually calibrated over standard baseline, plus GPS
- Zenith nadir plummet for centering tripods
- Fixed height prism pole for Total Station levelling
- Invar staff for instrument heighting, calibrated biennially.

MONUMENTATION AND NETWORK DESIGN

- Ideally instrument standpoints are stable bedrock anchored pillars;
- Pillars should have reference marks to monitor local deformation; and
- Survey marks should have an unambiguous reference point.

CONSISTENCY OF BIENNIAL SURVEYS

Three local tie surveys have been conducted at the Mt Stromlo Observatory:

1. Early 1999, after establishment of the SLR station and installation of GPS and DORIS equipment;
2. Early 2002, as part of the programmed two-year repeat survey cycle (labeled 2001 in the graphs);
3. Late 2003, after re-establishment following the firestorm of January 2003 which destroyed everything except the monuments and SLR calibration piers.

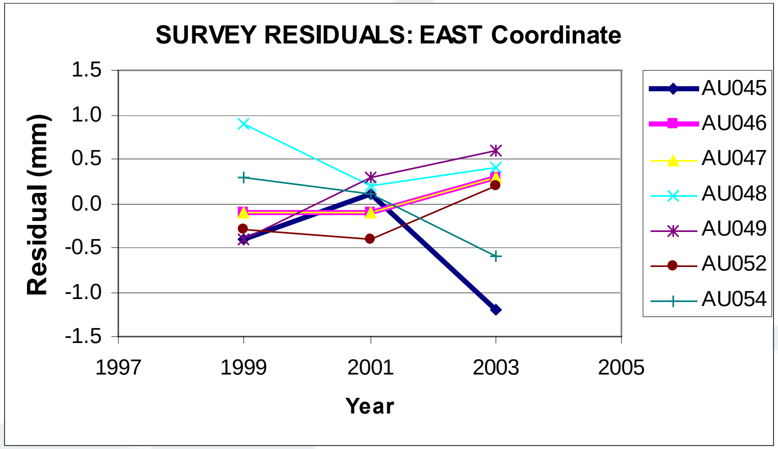
The next survey is scheduled for July 2006.

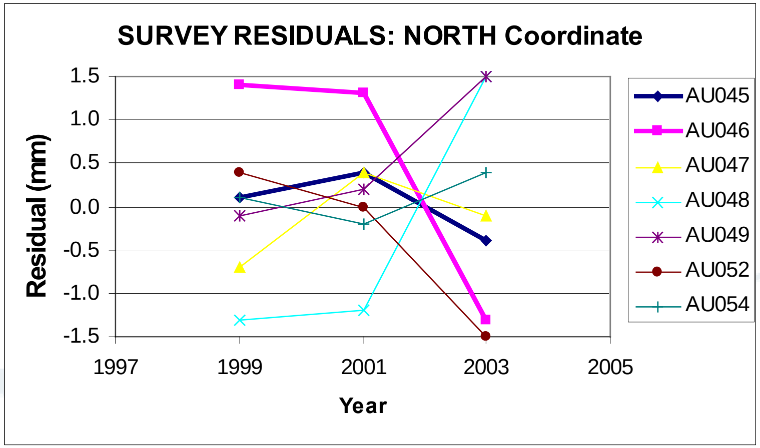
This work is performed by Geoscience Australia. They combined observations from all 3 surveys in a single combined solution, including the positions of the intersections of axes of the initial and replacement SLR telescopes. The graphs below show the differences at each survey from the combined solution of:

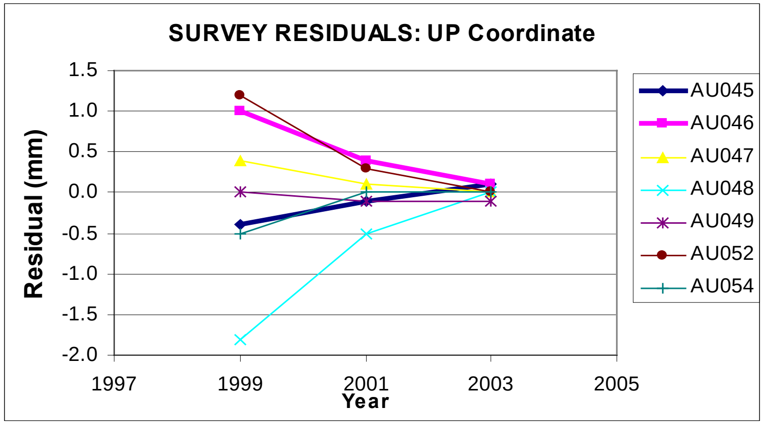
- AU045 – the Fundamental Monument;
- AU046 – AU049 – Plates on SLR Calibration Pillars North, North-East, South-East and South-West, on which the cal target reflectors are mounted;
- AU052 – STR1, the plate supporting a GPS antenna 0.183 metres above AU046;
- AU054 – Auxiliary monument, to the West of the SLR telescope.

SURVEY VARIABILITY

Spans 3 to 3.5 mm, hence **RMS ≤ 0.7 mm**. The formal solution RMSs are ~ 0.5 mm.







$$R_i = \left(2/c\right)\sqrt{\left[\left(x_i - X_0\right)^2 + \left(y_i - Y_0\right)^2 + \left(z_i - Z_0\right)^2\right]} + S + q_i + \varepsilon_i$$

SLR CALIBRATION VERIFICATION BY 4-TARGET RANGING

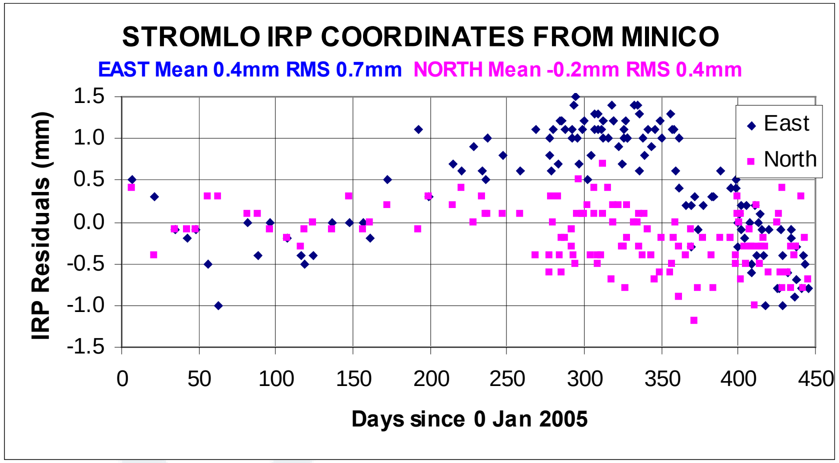
The aim of "calibration" is to determine the SYSTEM DELAY (S) during every pass, covering all the optical and electronic delays interior to the Instrumental Reference Point (IRP, generally the intersection of axes). Normally, this is accomplished by ranging pre- and post-pass to a single ground target retroreflector whose distance from IRP has been accurately determined by the local tie surveys. This is the routine procedure at Mt. Stromlo. In addition, this distance is regularly monitored by the MINICO technique of ranging to 4 ground targets roughly equally spaced around the IRP, at distances of 50-100 metres. See Fig.1. Nowadays, a MINICO is done daily.

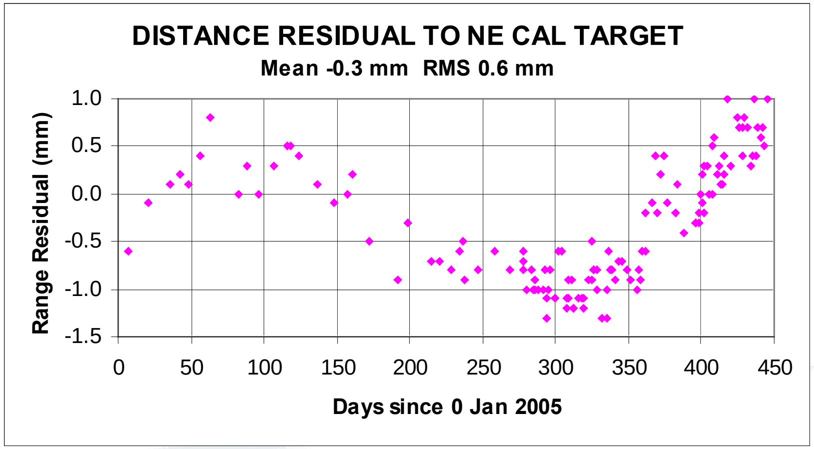
If R_i, i=1,4 is the measured 2-way time-of-flight range measurement to target i whose adopted East-North-Up coordinates are (x_i, y_j, z_j) and whose corrections q_i for atmospheric propagation, dome window glass thickness, etc. are known, and ε_i is random measurement error, then:

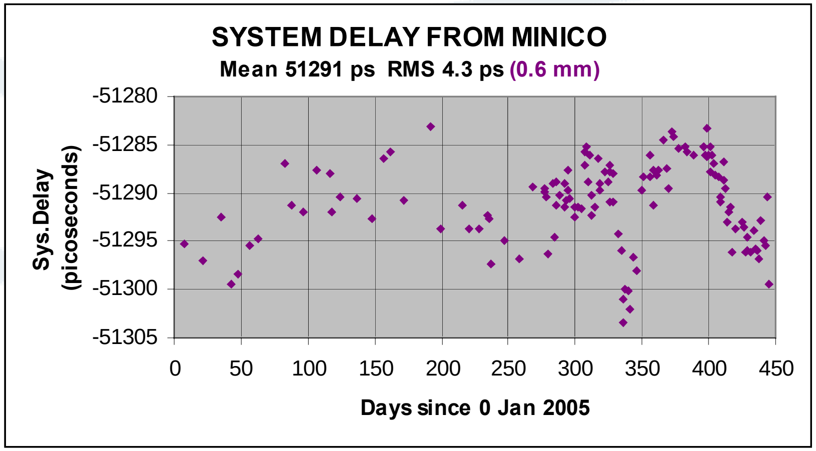
$$R_i = \left(2/c\right)\sqrt{\left[\left(x_i - X_0\right)^2 + \left(y_i - Y_0\right)^2 + \left(z_i - Z_0\right)^2\right]} + S + q_i + \varepsilon_i$$

which can be solved for the horizontal IRP coordinates X_0, Y_0 and system delay S. The geometry of the sub-network, and the limited redundancy, do not permit solution for the vertical IRP component Z_0. The adjusted values for the IRP then enable a refined calculation of the . . . . .

MINICO RESULTS







4-TARGET RANGING (CONT.)

distance to each target, especially the routine calibration target (North Pier). The constancy of the System Delay is an excellent indicator of overall system performance.

It is evident that there is an annual cycle of semi-amplitude 1mm in the distance to the North-East target, which aliases into an apparent variation of the East coordinate of the IRP – or perhaps vice versa! The cause has not been identified (March 2006).

CONCLUSION

The clarity of the variation amply demonstrates the accuracy and usefulness of the MINICO method. The next local tie survey is scheduled for the next expected peak in the cycle.

ACKNOWLEDGEMENTS

Gary Johnston and his team at Geoscience Australia have performed the surveys, processed the data and provided the results. Chris Moore at Electro Optic Systems manages the laser ranging activities at Stromlo and has provided the 'MINICO' data.