The 2002 Mount Pleasant (Hobart) Radio Telescope Local Tie Survey

GEOSCIENCE AUSTRALIA
RECORD 2004/21

by

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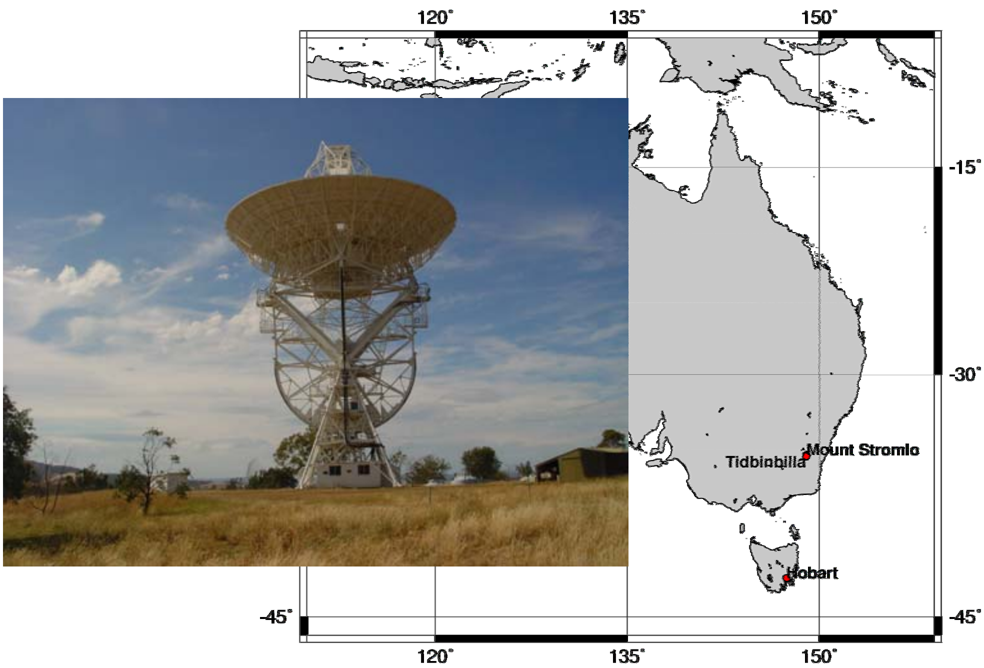

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ISSN 1448-2177
ISBN 1 920871 15 2

Bibliographic reference: Johnston G., Dawson J., 2004. The 2002 Mount Pleasant (Hobart) Radio Telescope Local Tie Survey. Geoscience Australia, Record 2004/21. 21pp.

Contents

Executive Summary

The Mt Pleasant Observatory is located near Hobart in Tasmania, Australia. The radio telescope, which is used for Very Long Baseline Interferometry (VLBI), is co-located with the permanent International GPS Service (IGS) GPS site (***HOB2***). A local tie survey at Mt Pleasant was completed in March 2002 by specialist Geoscience Australia Geodetic Surveyors using precision classical geodetic observations and geodetic GPS observations. The purpose of this survey was to repeat the determination of the relationship between the VLBI invariant reference point (***7242 A 50116S002***), the GPS reference point (***HOB2 A 50116M004***), and the surrounding survey control. This type of local tie survey has previously been undertaken at Mt Pleasant in 1995. This document reports on aspects of this survey.

Introduction

This report is not meant to serve as a manual for precision geodetic local tie surveys and it largely assumes that the reader has an understanding of the basic concepts of geodetic surveying. Furthermore, this report does not detail or justify the approach taken, but merely reports the results of each major computation step. However for completeness the steps in our approach for the observation and computation of local ties are as follows:

- *The calibration of all geodetic instrumentation including: total station instruments; levelling staffs; fixed height mounts; and reflectors (targets);*

- *The observation of a vertical geodetic network by application of geodetic levelling (in our case specifically EDM-Height traversing) to all survey marks in the vicinity of the observatory;*

- *The observation of a horizontal geodetic network by application of terrestrial geodetic observations, including angles and distances to all survey marks in the vicinity of the observatory;*

- *The observation of a Global Positioning System (GPS) network on suitable survey marks in the vicinity of the observatory (these marks are included in the geodetic levelling)*;

- *The observation of targets located on the observing system (Satellite Laser Ranging or Very Long Baseline Interferometry instrumentation) during rotational motion about each of its independent axes. This includes zenith angle observations to a staff on a levelled survey mark in the vicinity for precise height of instrument determination;*

- *The reduction of terrestrial geodetic observations, including the correction of observations for instrument and target bias, set reduction and atmospheric effects, and includes the height of instrument determination from observations to a staff;*

- *Classical geodetic least squares (minimum constraint) adjustment of all terrestrial geodetic observations, including deflection of the vertical and geoid corrections (derived from the Australian national gravimetric geoid). This results in terrestrial only coordinate estimates and their associated variance-covariance matrix (in a local system) of the geodetic network and targets located on the SLR and/or VLBI instrumentation;*

- *Invariant Point (IVP) modelling and estimation, includes the estimation of IVP, the axes of rotation and associated system parameters such as axis orthogonality and the offset of the axes; Includes readjustment of terrestrial only network;*

- *Analysis of GPS observations. This results in GPS only coordinate estimates and associated geocentric variance-covariance matrix;*

- *Transformation (translation and rotation only) of the readjusted terrestrial network and computed IVP coordinate variance-covariance matrix into a global reference frame including a geocentric variance-covariance matrix (estimated and apriori); The previous GPS analysis is used as the global reference frame realisation; and the*

- *Reduction of the complete solution to stations of primary interest (i.e. those with DOMES) and output of a SINEX format solution file including all apriori constraints.*

1. Site Description

The Mt Pleasant Observatory is located near Hobart in Tasmania, Australia. The radio telescope, which is used for Very Long Baseline Interferometry (VLBI), is co-located with the permanent IGS GPS site (HOB2).

Table 1*: List of survey marks with DOMES at the Mt Pleasant observatory.*

Local Designation	Global/IERS Designation
AU016 (or HOB2)	HOB2 A 50116M004
UF005 (or WEST PILLAR)	UF05 A 50116M001
UF003 (or NORTH PILLAR)	UF03 A 50116M002
VLBI IVP	7242 A 50116S002

A local tie survey at Mt Pleasant was completed in March 2002 by specialist Geoscience Australia Geodetic Surveyors using precision classical geodetic observations and geodetic GPS observations. The purpose of this survey was to repeat the determination of the relationship between the VLBI invariant reference point (***7242 50116S002***), the GPS reference point (***HOB2 50116M004***), and the surrounding survey control. This type of local tie survey has previously been undertaken at Mt Pleasant in 1995.

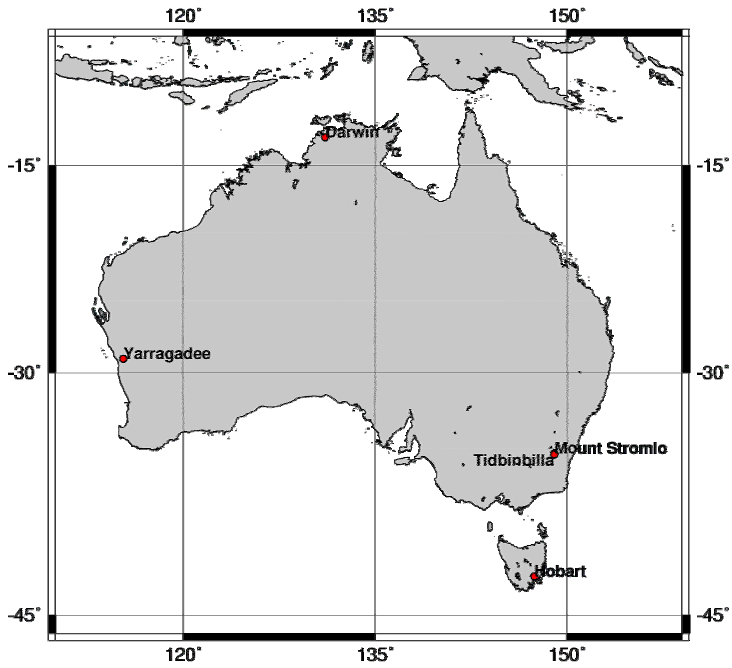


Figure 1*: The Mount Pleasant (Hobart) Very Long Baseline Interferometry (VLBI) station in Tasmania. The co-located observatory includes VLBI and GPS.*

***Figure 2**: The Mount Pleasant (Hobart) Very Long Baseline Interferometry (VLBI) station.*

2. Instrumentation

2.1 Tacheometers, EDMI, Theodolites

2.1.1 Description

Leica TCA2003 Total Station, SN 439124.

Specification:

- EDM (infrared) distance standard deviation of a single measurement (DIN 18723, part 6): 1mm + 1ppm;
- Angular standard deviation of a mean direction measured in both faces (DIN 18723, part 3): 0.15mgon (0.49").

2.1.2 Calibration results

Calibration performed by Leica Geosystems AG Heerbrugg, Switzerland. Inspection date: 10th December 2001:

- EDM (Infrared) distance standard deviation: m_0 = 0.2mm (Distances from 19.5m to 501.5m). Distance linearity: ±0.3mm (Distances from 2.25m to 120m);
- Angular standard deviation hozizontal: 0.09 mgon (0.29") and vertical: 0.09 mgon (0.29").

Reflector calibrations:

- Additive constant for Leica GPH1P precision prism is 34.4mm which is applied directly in the total station.
- Additive constant for Leica Retro-reflective tape is 0.0mm from front face.

Staff calibration:

- Staff used for instrument heighting (refer section 4.1) compared against invar staff by Geoscience Australia.

2.1.3 Auxiliary equipment

Meteorological observations recorded by the Mt Pleasant radio telescope meteorological station.

2.2 GPS Units

GPS observations were made at three monuments in the terrestrial network, namely HOB2 (permanent IGS station), UF003 and UF005. The GPS analysis undertaken within the International Terrestrial Reference Frame 2000 (ITRF2000) was used to align the local terrestrial network to ITRF2000.

2.2.1 Receivers

```
+SITE/RECEIVER
*SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION
 HOB2  A ---- P 02:080:08910 02:081:86369 ASHTECH Z-XII3
 UF03  A ---- P 02:080:08910 02:081:86369 ASHTECH Z-XII3
 UF05  A ---- P 02:080:08910 02:081:86369 ASHTECH UZ-12
-SITE/RECEIVER
```

2.2.2 Antennas

```
+SITE/ANTENNA
*SITE PT SOLN T DATA_START__ DATA_END____ DESCRIPTION
 HOB2  A ---- P 02:080:08910 02:081:86369 AOAD/M_T
 UF03  A ---- P 02:080:08910 02:081:86369 ASH700936E
 UF05  A ---- P 02:080:08910 02:081:86369 ASH701945C_M
-SITE/ANTENNA
```

2.2.3 Analysis software, mode of operation

```
+SOLUTION/EPOCHS
*CODE PT SOLN T _DATA_START_ __DATA_END__ _MEAN_EPOCH_
 HOB2  A    1 P 02:080:08910 02:081:86369 02:081:04440
 UF03  A    1 P 02:080:08910 02:081:86369 02:081:04440
 UF05  A    1 P 02:080:08910 02:081:86369 02:081:04440
-SOLUTION/EPOCHS
```

2.3 Levelling

The EDM-height traversing technique was used as described in 4.2.

2.3.1 Levelling instruments

Refer to section 2.1.1

2.3.2 Levelling Rods

Fixed height stainless steel rod approximately 1.5m in height with Leica bayonet mount on top for mounting precision prism.

2.3.3 Checks carried out before measurement

Multi-set (repetition), dual face observations are taken to each target eliminating collimation effects. The offset in length between the 1.5m pole and the 0.2m stub used on pillars is determined by observing both on a low mark and calculating the offset. No other pole calibration is required.

2.4 Tripods

Leica GST20/9 Heavy duty timber tripods.

2.5 Forced centering devices

Leica Zenith & Nadir Plummet S/N F.NR.272713

2.6 Targets, reflectors

Total station target kits include:

- Leica GDF21 Tribrach
- Leica GZR3 prism carrier with optical plummet
- Leica GPH1P precision prism

3. Measurement Setup

3.1 Ground Network

3.1.1 Listing

26 METRE VLBI RADIO TELESCOPE - IVP: 7242 50116S002. 26 Metre Radio Telescope. The orthogonal projection of the vector defining the Y axes onto the X-axes. The Y and X-axes do not intersect.

AU016 (HOB2): HOB2 50116M004**.** The intersection of the top of the stainless steel plate with the vertical axis of a 5/8"ϕ Whitworth threaded stainless steel spigot. The pillar plate is set into the top of a 0.5 m high concrete pillar 0.6 m in diameter. The Dorne Margolin T - GPS antenna currently occupies this monument.

UF003 (NORTH PILLAR): UF03 A 50116M002. The intersection of the top of a stainless steel plate with the vertical axis of a 5/8"ϕ Whitworth threaded stainless steel spigot. The pillar plate is set into the top of approx. 1.6 m high concrete pillar 0.4 m in diameter.

UF005 (WEST PILLAR): UF05 A 50116M001. The intersection of the top of a stainless steel plate with the vertical axis of a 5/8"ϕ Whitworth threaded stainless steel spigot. The pillar plate is set into the top of approx. 1.6-m high concrete pillar 0.4-m in diameter.

SSPIN (Stainless Steel Pin) is a stainless steel pin set drilled into bedrock.

GRAV: Bronze domed plaque set in the concrete floor. Plaque is inscribed “Absolute Gravity Station, Hobart, 9699.9160, Commonwealth of Australia”. The coordinate refers to a punch hole in the centre of the plaque.

GRAV RM: Bronze disc (permanent survey mark) set in rock adjacent to the absolute gravity hut. The mark is an eccentric gravity mark for the absolute gravity station (GRAV). It is otherwise referred to as 9691.0160.

3.1.2 Map of network

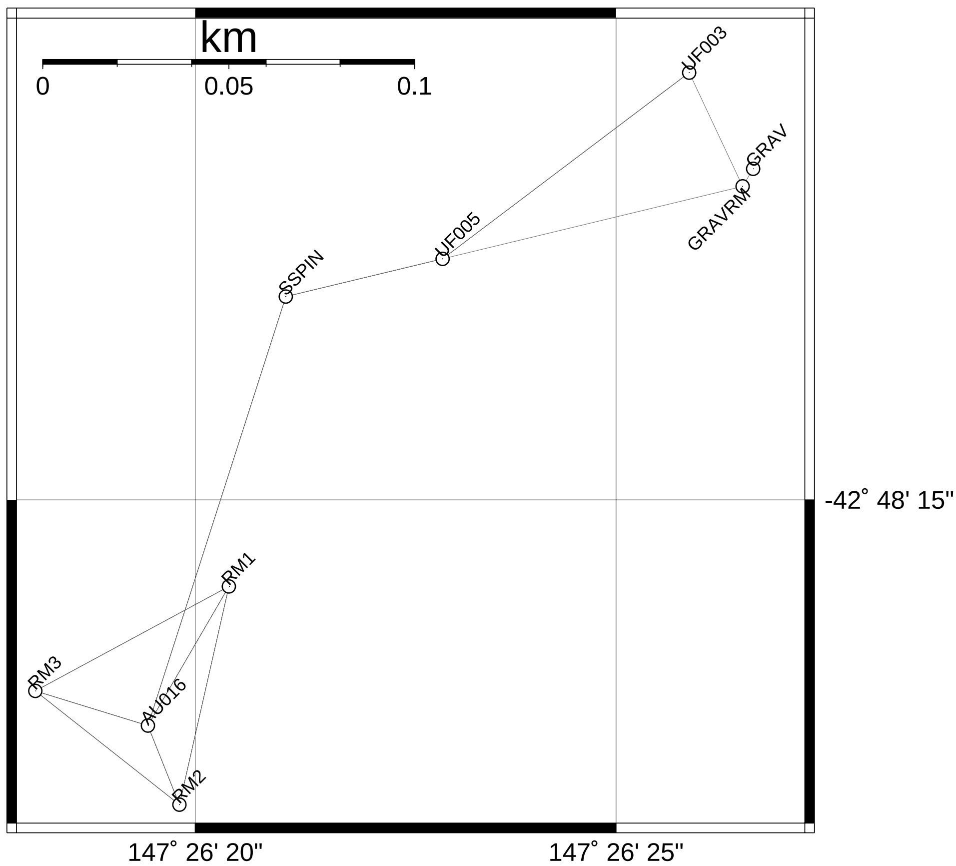


Figure 3*: The Mount Pleasant (Hobart) terrestrial geodetic network. Terrestrial observations (excludes observations for IVP determination) between stations are shown as inter-connecting lines.*

3.2 Representation of Reference Points

3.2.1 VLBI

The Mount Pleasant radio telescope invariant reference point or IVP is defined as the intersection of the primary axis with common perpendicular of the primary (X) and secondary (Y) axes. A method based on 3-dimensional circle fitting is applied as the basis for IVP determination. Three dimensional coordinate observations to targets observed on the radio telescope during rotational sequences are used to determine the independent axes of rotation. Multiple realizations of the secondary axis (i.e. observed at multiple primary axis settings) are observed and computed. A least squares method is used for the computation of the axes of rotation and the IVP. A target located on a rigid body, rotating about one independent axis can be fully expressed as circle in 3-dimensional space. This circle can be described by seven parameters, namely the circle centre (3 parameters), a unit normal vector perpendicular to the plane of the circle and a circle radius parameter (1 parameter). A constraint that the unit normal vector perpendicular to the plane of the circle must have magnitude one is required, as is a minimum of three rotational sequences to enable the solution of the equation of a circle.

The method makes the following assumptions: during rotational sequence target paths scribe a perfect circular arc in 3D space; there is no deformation of targeted structure during rotational sequence; there is no wobble error; and the axis of interest can be rotated independently of the other axis. No assumptions of axis orthogonality, verticality/horizontality or the precise intersection of the axes are made.

The indirect geometrical model includes a number of conditions, including:

- Target paths during rotation about an independent axis scribe a perfect circle in space;
- Circle centres derived from targets observed while being rotated about the same axis are forced to lie along the same line in space;
- Normal vectors to each circle plane derived from targets observed while being rotated about the same axis are forced to be parallel;
- The orthogonality of primary axis to the secondary axis remains constant over all realisations of the secondary axis;
- Identical targets rotated about a specific realisation of an axis will scribe 3-dimensional circles of equal radius;
- The offset distance between the primary axis and secondary axis remains constant over all realisations of the secondary axis;
- The distance between 3-dimensional circle centres for all realizations of the secondary axis are constant over all realisations of the secondary axis; and
- The IVP coordinate estimates remain constant over all realisations (combinations) of the primary/secondary axis;

Because the 3-dimensional circle (described by seven parameters) includes a normal vector to the circle plane, the following constraint is also applied;

- The unit normal vector perpendicular to the circle plane is of magnitude one;

The linearized equations take the form of two sets of equations, namely conditions and constraints with added parameters

$$Av + B\Delta = f$$
$$D_1\Delta + D_2\Delta' = h$$

where v is the parameter vector of residuals of the input classical adjustment results, Δ is the parameter vector of the circle parameters, Δ' is the parameter vector of the parameters associated with the IVP estimates, f and h are the constant vectors associated with the evaluation of the conditions and constraints respectively and A, B, D_1 and D_2 are matrixes of coefficients. The least squares solution is obtained from the following system of normal equations

$$\begin{bmatrix} -W & A^t & 0 & 0 & 0 \\ A & 0 & B & 0 & 0 \\ 0 & B^t & 0 & D_1^t & 0 \\ 0 & 0 & D_1 & 0 & D_2 \\ 0 & 0 & 0 & D_2^t & 0 \end{bmatrix} \begin{bmatrix} v \\ k \\ \Delta \\ k_c \\ \Delta' \end{bmatrix} = \begin{bmatrix} 0 \\ f \\ 0 \\ h \\ 0 \end{bmatrix}$$

where W is the weight matrix of the input coordinates derived from the classical adjustment and k and k_c are vectors of Lagrange multipliers required to satisfy the Least Squares criteria.

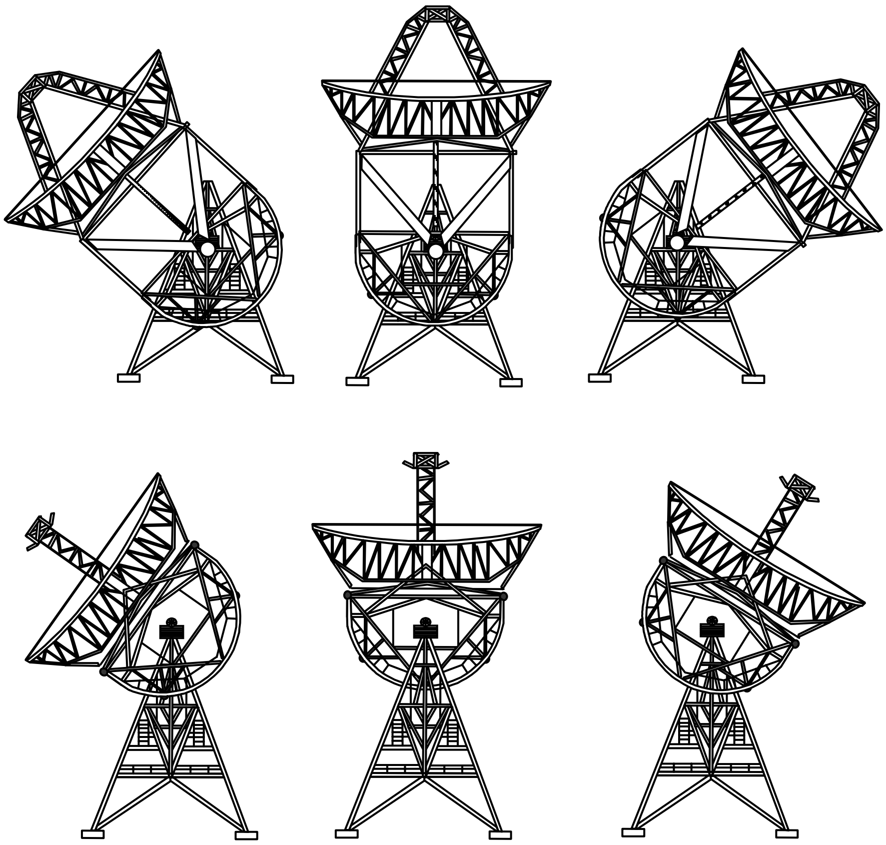


***Figure 4**: X/Y type radio telescope axes of rotation; Top figure shows rotation about the primary axis; Bottom shows rotation about the secondary axis.*

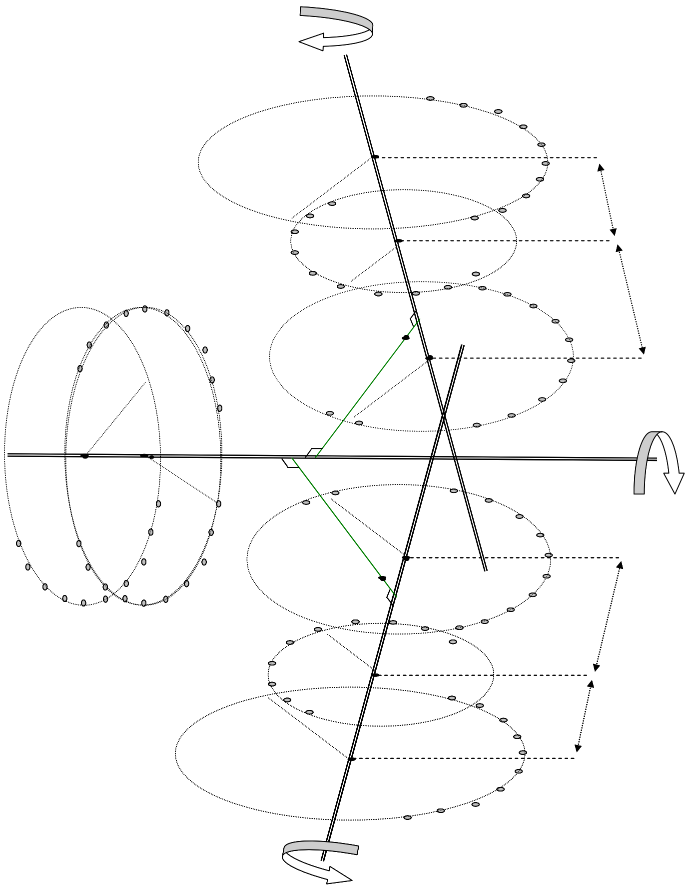


***Figure 5**: IVP model. Circle centres derived from targets observed while being rotated about the same axis are forced to lie along the same line in space; Normal vectors to the circle plane derived from targets observed while being rotated about the same axis are forced to be parallel; Note that to simplify the diagram only two targets are shown on the primary axis and three targets are shown on the secondary axis. The two realisations of the secondary axis allow for the constraint of the circle radius parameters, as can the inter-circle centre distances. The angle between the secondary and primary axis (i.e. axis orthogonality) should be constant over all realisations of the secondary axis. The IVP estimate should be constant over all realisations of secondary/primary axis combinations.*

The solution to the normal equation system is iterated as required for the non-linear condition and constraint equations. An updated estimate of the input coordinates and their variance-covariance matrix is obtained together with an estimate of the IVP coordinate their variance-covariance matrix and the inter-relating covariance matrix.

***Table 2**: Mount Pleasant 2002 survey IVP determination observations.*

Axis	Number of targets	Description/Comment
Primary	7	*Secondary axis fixed at 90° from zenith (ie. Antenna cone passes through zenith);* *Primary axis rotated in 10° increments;* *Primary axis can rotate through 166°;* *System was observed from UF05 50116M001;* *Tape targets used.*
Secondary 1st realization	7	*Secondary axis rotated in 10° increments;* *Primary axis fixed at 0° (ie. Antenna cone passes through zenith);* *Secondary axis can rotate through 130°;* *Secondary axis realized from observations at UF03 A 50116M002;* *Tape targets used.*
Secondary 2nd realization	7	*Secondary axis rotated in 10° increments;* *Primary axis fixed at 20° (ie. Antenna cone passes through zenith-20°);* *Secondary axis can rotate through 130°;* *Secondary axis realized from observations at UF03 A 50116M002;* *Tape targets used.*

3.2.2 SLR

No SLR system at Mt Pleasant.

3.2.3 GPS

In the case of Mt Pleasant the GPS antenna is removed during the survey and the reference point is observed directly.

3.3.4 DORIS

No DORIS system at Mt Pleasant.

3.3.5 GLONASS

No GLONASS system at Mt Pleasant.

4. Observations

4.1 Conventional survey

The Figure 3 network diagram illustrates the network observed. HOB2, UF005 and UF003 are concrete pillars. At these sites the instrument and target tribrachs were mounted directly on the spigot. At the other monuments a tripod was set up over the monument using the Zenith Nadir Plummet.

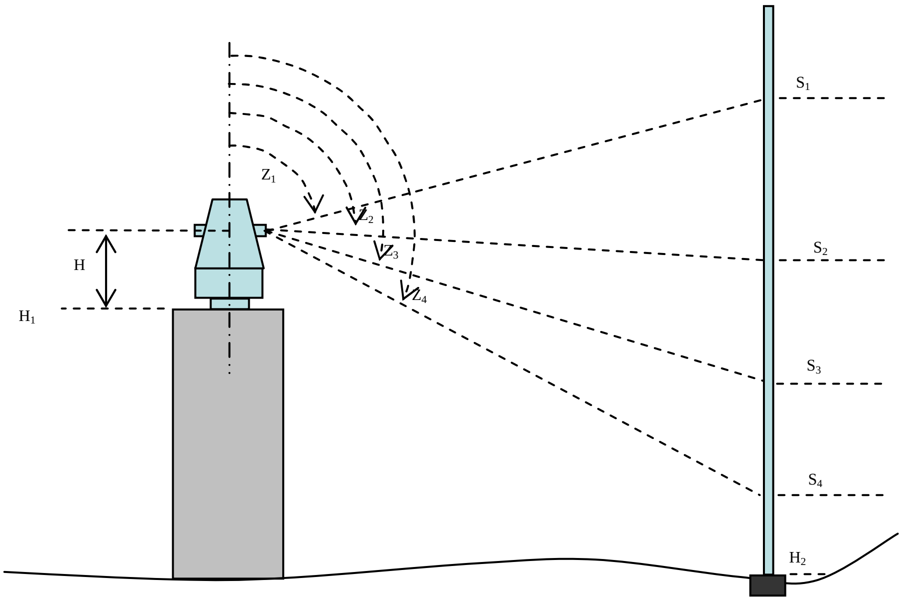
Generally five sets of observations were completed at each standpoint. A set consists of a round of face left observations, followed by the reverse round of face right observations. Slope distances and zenith angles were recorded for each observation as well. Atmospheric corrections were not applied in the instrument, but later applied to distances in post processing using conventional correction formulae and local meteorological observations.

The heights of instrument were observed using the technique illustrated in Figure 7. Vertical angles are observed to graduation boundaries on a normal levelling staff. This technique routinely returns values for height of instrument accurate to 0.1mm. The technique is strongest when the mid height of the levelling staff is approximately horizontal from the instrument trunion axis. The technique relies on the height difference between the ground marks (H_1 and H_2) being determined independently to these observations. In the case of this survey the monuments were included in the levelling survey discussed in 4.2.

Observations into the VLBI telescope for the indirect determination of the IVP were performed from two standpoints (UF003 and UF005). For the determination of the X axis retro-reflective tape targets were placed along the X-axis bull. The targets were observed as detailed in section 3.2. For the Y-axis retro-reflective tape targets were placed on the Y-axis bull gear, which provided a flat surface, see Figure 6.

Figure 6*: Location of targets and points of interest on the Mt Pleasant VLBI Telescope.*

Observations to the targets during these rotational sequences consisted of a single set of dual face pointings, commencing and terminating on an external reference object (network station) for orientation.



$$H = \frac{S_2 \cot Z_1 - S_1 \cot Z_2}{\cot Z_1 - \cot Z_2} - (H_1 - H_2)$$

Figure 7: *Total station instrument heighting technique, where S_n are staff readings; Z_n are zenith angles (Rueger & Brunner, 1981).*

4.2 Levelling

The levelling for this survey was carried out using the EDM-height traversing technique. It comprises height difference observations to a prism mounted on a fixed height prism pole, which is braced by a bi-pole and placed over the survey mark. Differential heighting can then be achieved. This technique minimises thermal expansion effects and refraction caused by thermal flux since the lines of sight are near to parallel to the ground surface.

Where pillar monuments are used a prism mounting stub (approximately 0.2m in length) which screws directly onto the 5/8" ϕ Whitworth threaded stainless steel spigot is used.

Levelling loops covering all the monuments in the network were completed in both directions. The results were then adjusted in the least squares sense giving adjusted height differences between all marks.

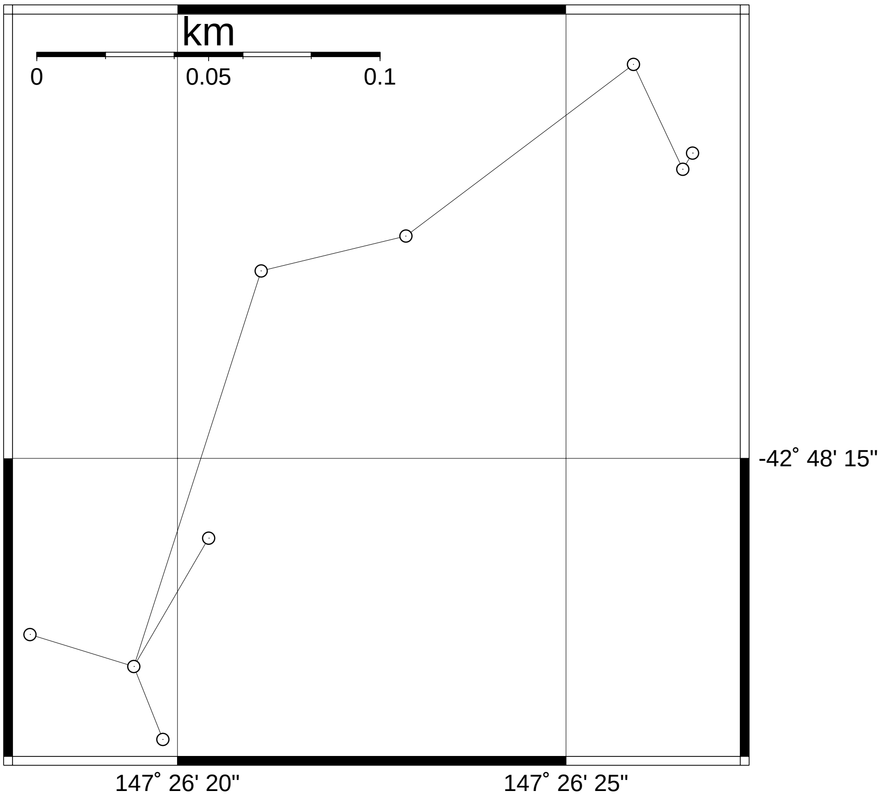


Figure 8: *Hobart 2002 survey levelling observations. Direct observations between stations are shown as inter-connecting lines.*

4.3 *GPS*

Refer to section 5.2.1

4.4 General comments

None.

5. Data Analysis and Results

The flow chart of the analysis process used for the Hobart survey is detailed in Figure 9. Coordinate solutions are generated in three steps; firstly at the completion of the classical geodetic adjustment (*Step A*); secondly at the completion of the geometrical modelling where the impact of the geometrical model is propagated throughout the input classical adjustment results (*Step B*); and thirdly after transformation (rotation and translation) of 'geometrically modified` solution onto the required global reference frame (*Step C*). In this report the results of *Step A* are reported in section 5.1.2 and 5.1.3; and the results from *Step C* are reported in section 5.2.2, the results from *Step B* are not reported.

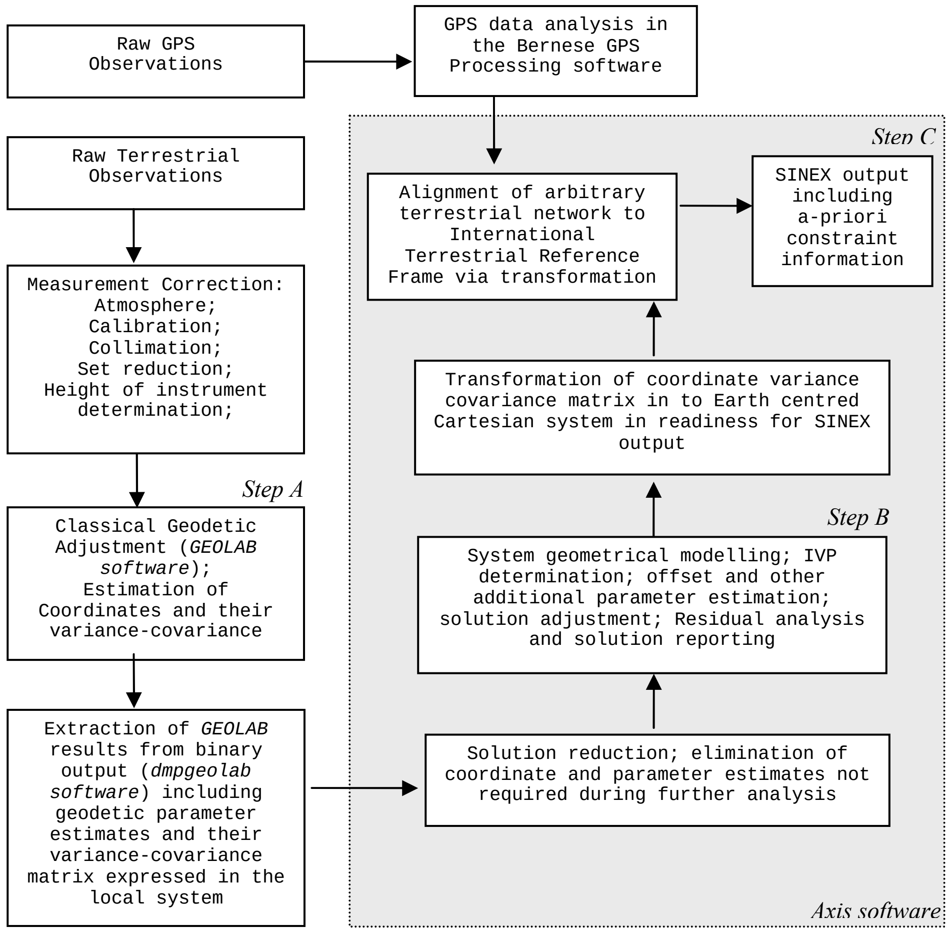


***Figure 9**: Analysis process for the reduction of local survey data.*

5.1 Terrestrial Survey

5.1.1 Analysis Software

Classical geodetic adjustment is undertaken in *GEOLAB* version 2.4d. Deflections of the vertical and geoid undulation corrections were applied using ***AUSGEOID98*** (Johnston & Featherstone, 1998). Extraction of the solution data, including a full variance-covariance matrix, from the propriety binary GEOLAB format into ASCII format is undertaken using the Geoscience Australia developed *dmpgeolab* software (version 0.00). The geometrical modelling, adjustment and transformation processes are undertaken in the Geoscience Australia developed *axis* software (version 1.01).

5.1.2 Topocentric coordinates and covariances

Geodetic coordinates (GRS80 Ellipsoid) provided in the arbitrary local terrestrial system before alignment to the ITRF2000 are given below:

***Table 3**: Hobart 2002 terrestrial survey results. GRS80 ellipsoid. Heights are ellipsoidal, arbitrary local system.*

STATION		LONGITUDE			LATITUDE			HEIGHT (m)
RM1_	RM1------	147	26	20.40379	-42	-48	-15.75615	43.7863
RM2_	RM2------	147	26	19.81488	-42	-48	-17.66023	38.7415
RM3_	RM3------	147	26	18.10515	-42	-48	-16.66803	39.4938
GRAV	GRAV-----	147	26	26.62842	-42	-48	-12.11642	51.3588
HOB2	50116M004	147	26	19.44198	-42	-48	-16.97092	41.0706
SSPI	SSPIN----	147	26	21.07726	-42	-48	-13.22875	46.9564
UF03	50116M002	147	26	25.86701	-42	-48	-11.27794	51.0112
UF05	50116M001	147	26	22.93722	-42	-48	-12.90052	52.2221
GRRM	GRAVRM---	147	26	26.50224	-42	-48	-12.26629	51.3758

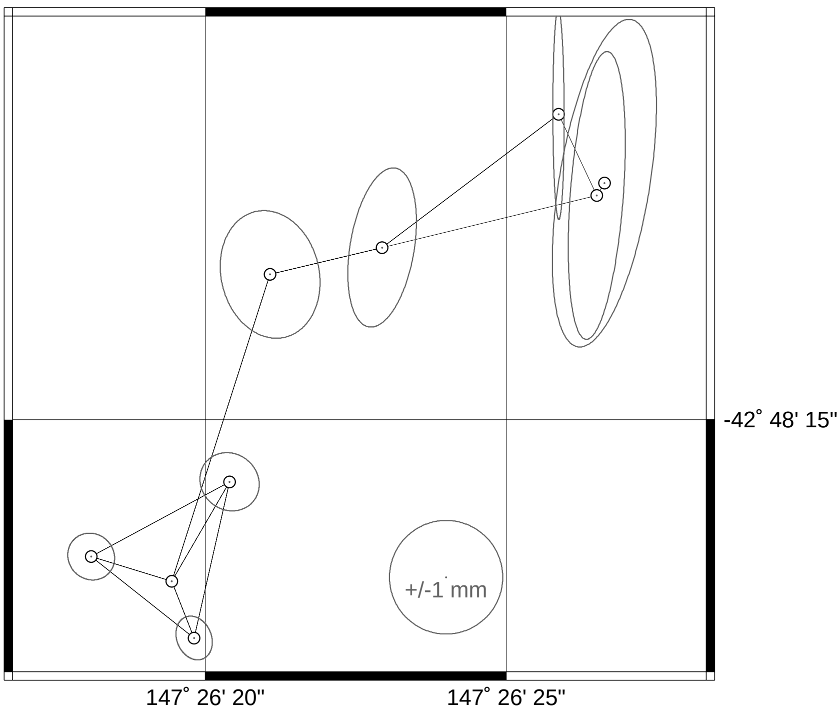


***Figure 10**: Hobart 2002 terrestrial network, error ellipses are 95% confidence. Direct observations between stations are shown as inter-connecting lines.*

5.1.3 Correlation matrix

The computed correlation matrix is too large to be included in this report, please refer to the SINEX file (see section 5.5) for further information of this type.

5.1.4 Reference temperature

No thermal corrections have been applied for temperature dependent structural expansion of the VLBI instrument, although ideally this correction should be applied the model has not been implemented in our computation procedure (e.g. McCarthy & Petit, 2004).

5.2 GPS

5.2.1 Analysis software

The GPS data analysis was undertaken using the Bernese GPS Processing Software Version 4.2 (Hubentobler U., S. Schaer, P. Fridez, Bernese GPS Software Version 4.2, *Astronomical Institute, University of Berne, 2001)*. International Terrestrial Reference Frame 2000 (ITRF2000) coordinates of the permanent GPS monument, ***HOB2 50116M004***, were adopted at the epoch of observation. Both L1 and L2 observations were used and no troposphere model parameters were estimated. The observations were processed to a 10º cut-off. Carrier phase ambiguities were resolved to their integer values in all cases. Final International GPS Service (IGS) orbits and Earth orientation parameters were used for computations. IGS recommended constant and elevation dependent antenna phase models were applied.

5.2.2 Results

Table 4*: Hobart 2002 GPS survey results, GRS80 ellipsoid. Heights are ellipsoidal, ITRF2000 at date of survey.*

STATION	LONGITUDE			LATITUDE			HEIGHT (M)
HOB2 50116M004	147	26	19.44192	-42	-48	-16.97094	41.0833
NRTH ---------	147	26	25.86693	-42	-48	-11.27796	51.0241
WEST ---------	147	26	22.93704	-42	-48	-12.90037	52.2358

5.3 Additional Parameters

Additional system parameters were computed during the IVP estimation process. The azimuth of the primary (X) axis is 359° 58’ 31.4”. The azimuth of the secondary (Y) axis is 89° 58’ 34.7”. The orthogonality (or non-orthogonality) of the primary (X) to the secondary (Y) axes was estimated to be 90° 00’ 3.2”. The offset distance between the primary (X) and secondary (Y) axis was estimated to be 8.1913 m.

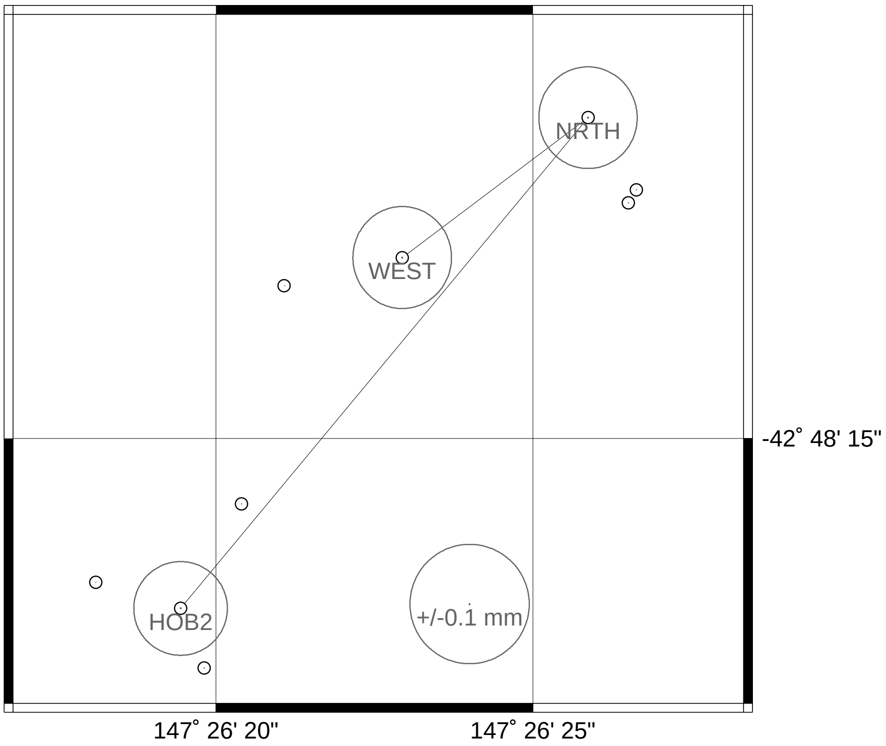


Figure 11*: Hobart 2002 GPS Network, error ellipses are 95% confidence. GPS baselines are shown as inter-connecting lines.*

5.4 Transformation

The arbitrary terrestrial network is aligned to the International Terrestrial Reference Frame by means of a six parameter transformation, namely three translations and three rotations. This ensures that the scale of the network as realised through the calibrated total station distance measurements is adopted in the final solution.

Table 5: *Hobart 2002, local to ITRF2000 alignment results.*

ALIGNMENT RESIDUALS

	UNTRANSFORMED-REFERENCE			TRANSFORMED-REFERENCE		
SITE	X	Y	Z	X	Y	Z
AU016	0.0068	-0.0059	0.0089	0.0004	-0.0013	-0.0006
UF003	0.0054	-0.0055	0.0100	0.0017	-0.0015	-0.0016
UF005	0.0090	-0.0097	0.0058	-0.0021	0.0028	0.0022

	UNTRANSFORMED-REFERENCE			TRANSFORMED-REFERENCE		
SITE	EAST	NORTH	UP	EAST	NORTH	UP
AU016	0.0013	0.0005	-0.0126	0.0009	-0.0011	-0.0004
UF003	0.0017	0.0022	-0.0123	0.0003	-0.0027	-0.0006
UF005	0.0034	-0.0045	-0.0133	-0.0012	0.0038	0.0009

TRANSFORMATION PARAMETERS

CARTESIAN SYSTEM - CENTROID ORIGIN

VARIANCE FACTOR : 2.93937e-06
SIGMA : 1.71446e-03

TX	TY	TZ	RX	RY	RZ
M	M	M	AS	AS	AS
0.0073	-0.0073	0.0084	4.29	1.24	-2.58

RESIDUAL SCALE BIAS 4.3 PPM

5.5 Description of SINEX generation

The SINEX naming convention adopted by Geoscience Australia for local survey data is:

XXXNNNNYYMMFV.SNX

where

XXX is a three character organisation designation;
NNNN is a four character site designation;
YY is the year of survey;
MM is the month of survey,;
F is the frame code (G for global frame; L for local frame); and
V is the file version.

The SINEX file corresponding to this report is ***AUSHOBA0203GA.SNX***, and can be found at ftp://ftp.ga.gov.au/sgac/sinex/ties/. This file supersedes the SINEX file aus00c02.snx submitted to the International Earth Rotation Service (IERS) in 1999 for the ITRF2000 computation.

5.6 Discussion of results

Table 6: *Hobart 2002, final results, geodetic coordinates, GRS80 ellipsoid (degrees, minutes, seconds, metres), ITRF2000 at date of survey.*

STATION	LONGITUDE	LATITUDE	HEIGHT (M)
HOB2 50116M004	147 26 19.44188	-42 -48 -16.97090	41.0837
UF03 50116M002	147 26 25.86692	-42 -48 -11.27788	51.0246
UF05 50116M001	147 26 22.93710	-42 -48 -12.90049	52.2350
7242 50116S002	147 26 25.86727	-42 -48 -12.90047	65.1224

Table 7: *Hobart 2002, final precision estimates of the geodetic coordinates (1σ, metres).*

STATION	LONGITUDE (M)	LATITUDE (M)	HEIGHT (M)
HOB2 50116M004	0.0001	0.0001	0.0001
UF03 50116M002	0.0001	0.0019	0.0002
UF05 50116M001	0.0006	0.0014	0.0002
7242 50116S002	0.0007	0.0018	0.0002

Table 8: *Hobart 2002, final results, cartesian coordinates (metres), ITRF2000 at date of survey.*

STATION	X (M)	Y (M)	Z (M)
HOB2 50116M004	-3950071.5762	2522415.2382	-4311638.1615
UF03 50116M002	-3950256.9030	2522360.3620	-4311516.0252
UF05 50116M001	-3950193.1480	2522398.6393	-4311553.5843
7242 50116S002	-3950236.9502	2522347.6119	-4311562.3406

Table 9: *Hobart 2002, final precision estimates of the cartesian coordinates (1σ, metres).*

STATION	X (M)	Y (M)	Z (M)
HOB2 A 50116M004	0.0001	0.0001	0.0001
UF03 A 50116M002	0.0011	0.0007	0.0014
UF05 A 50116M001	0.0010	0.0006	0.0010
7242 A 50116S002	0.0013	0.0005	0.0014

Table 10: *Hobart 2002, final results, cartesian difference vectors (metres), arbitrary local terrestrial system.*

FROM STATION		TO STATION	X(M)	Y(M)	Z(M)
HOB2 50116M004	-	UF03 50116M002	-185.3268	-54.8762	122.1363
HOB2 50116M004	-	UF05 50116M001	-121.5718	-16.5988	84.5773
HOB2 50116M004	-	7242 50116S002	-165.3740	-67.6263	75.8209

The least squares solution of the VLBI IVP position included; 21 targets; 2 IVP estimates (constrained together); 903 pseudo-observations; 143 unknowns; 34 additional unknowns; 596 conditions; 37 constraints and 106 additional constraints. The resultant linear system was 1823 x 1823 with degrees of freedom 1461. The computed variance factor was 0.9233. IVP model (circle) fit residuals were 1.1 mm Root Mean Square Error (RMS) for the in-plane residuals and 1.6 mm for the out-of-plane residuals.

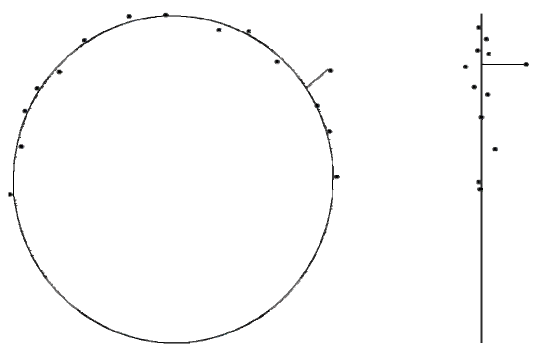


Figure 12*: Circle fitting residuals; left in-plane residuals; Right out-of-plane residuals.*

The Root Mean Square Error (RMS) of the terrestrial coordinate observations to the IVP model were 0.8 , 1.8 and 0.7 millimetres in the east, north and up components respectively. Thus, all indications are that this survey is approaching the 1 to 2 millimetre level accuracy. Although antenna specific GPS antenna phase centre variations remain un-modelled in this analysis.

5.7 Comparison with previous surveys

There is good agreement between the 1995 and 2002 surveys, RMS differences between the two network realisations are 0.7, 0.8 and 0.3 mm in north, east and up components respectively.

***Table 11**: Shows the residuals between the 1995 survey transformed onto the 2002 survey.*

Site	North (mm)	East (mm)	Up (mm)
AU016	-0.7	-0.1	-0.4
UF003	-0.0	0.8	0.1
UF005	0.7	-0.7	0.2
RMS	**0.7**	**0.8**	**0.3**

6. Planning Aspects

The terrestrial network at Mt Pleasant is poorly determined because of its traverse shape that allows very little redundancy. The placement of additional survey marks will significantly strengthen this network.

The accuracy of observations taken to retro-reflective tape is highly dependant on the angle of incidence of the observing ray. This is particularly significant with large VLBI telescopes. Future surveys will use magnetic mounted corner cube reflectors, which maintain their accuracy despite non-orthogonality.

The observation of GPS data is a significant component of the overall survey. In this survey one of the GPS antennae was found to be faulty. Its phase model did not adhere to the published IGS models for that antenna. The observation of suitable data spans with calibrated antennae needs to be completed. Scheduling this amongst terrestrial survey activities needs to be well planned.

While local tie surveys are a significant technique for reference frame definition, every attempt should be made to minimise disruption to normal telescope activities. Observations to the telescope in this survey were generally undertaken in scheduled periods of low tracking activity.

7. References

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7.3 Location of observation data and results archive

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