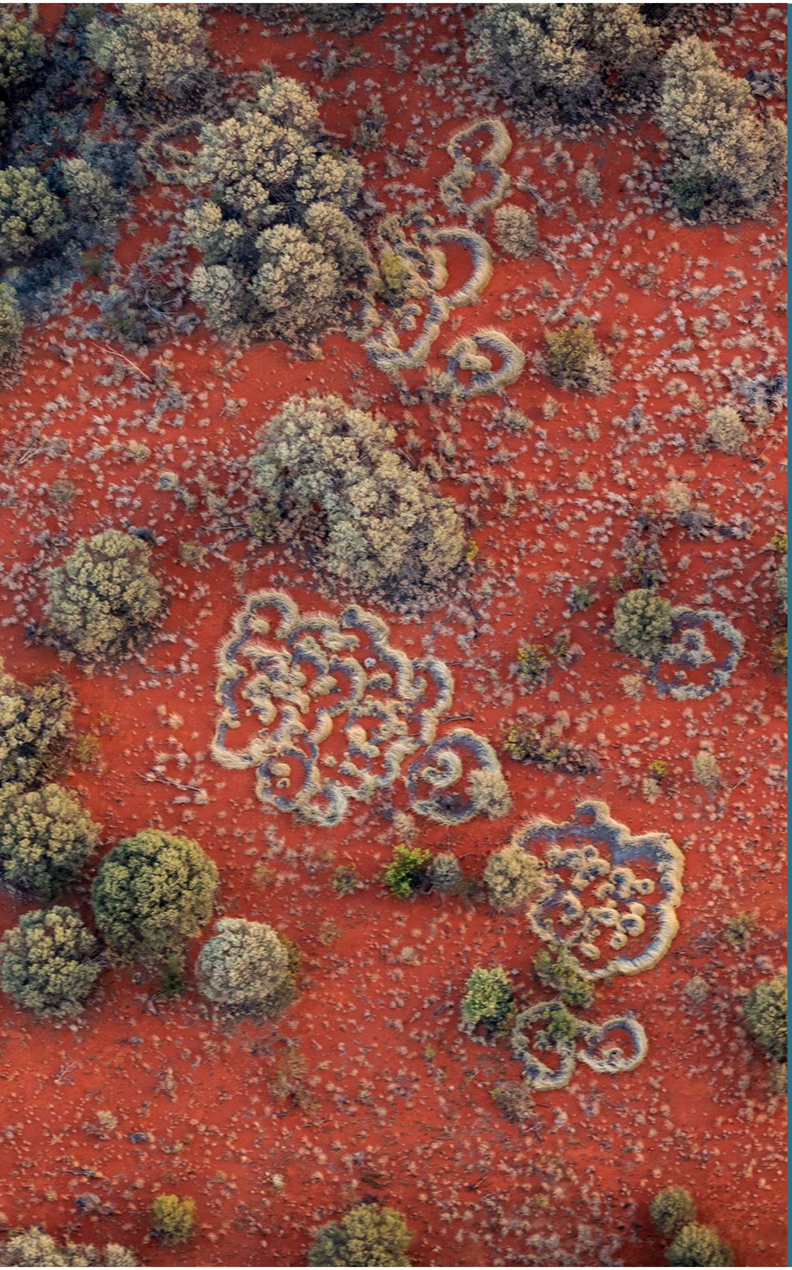

Australian Government
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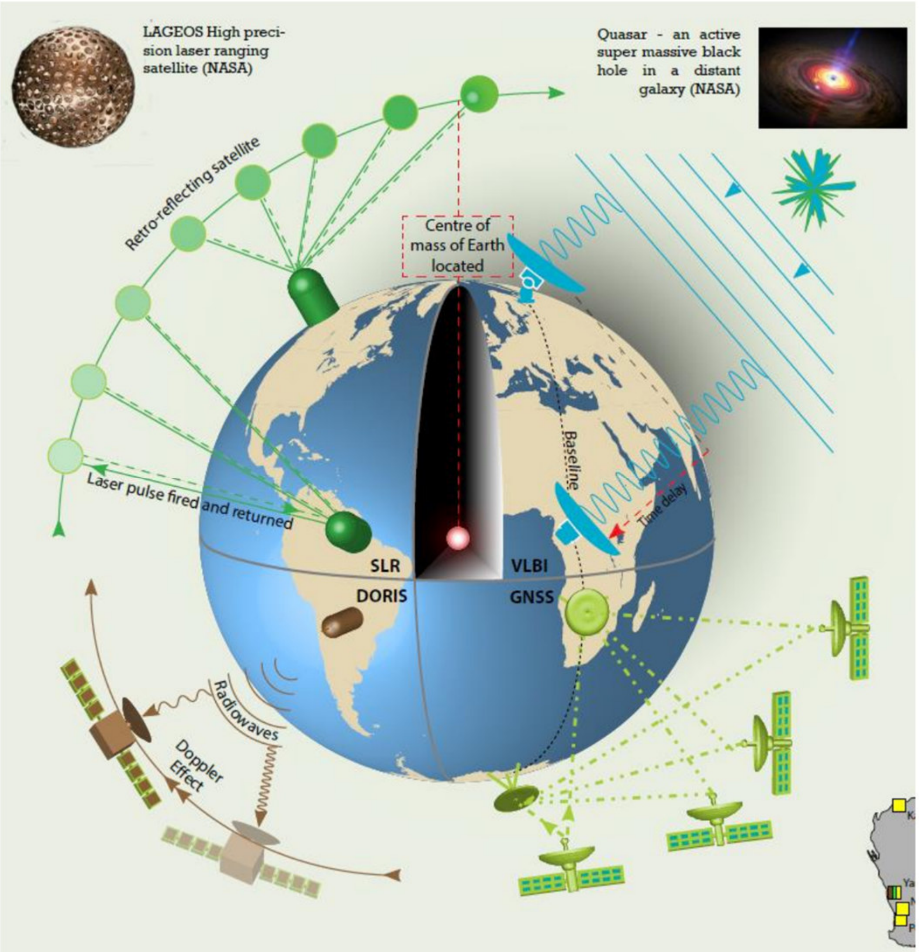
Positioning Australia

Balancing Best Practices with Innovation:

Developing a sustainable program for Local Tie Surveys at Australian Geodetic Observatories

Bart Thomas | Geodetic Surveyor

Local Tie Survey of Co-located Systems

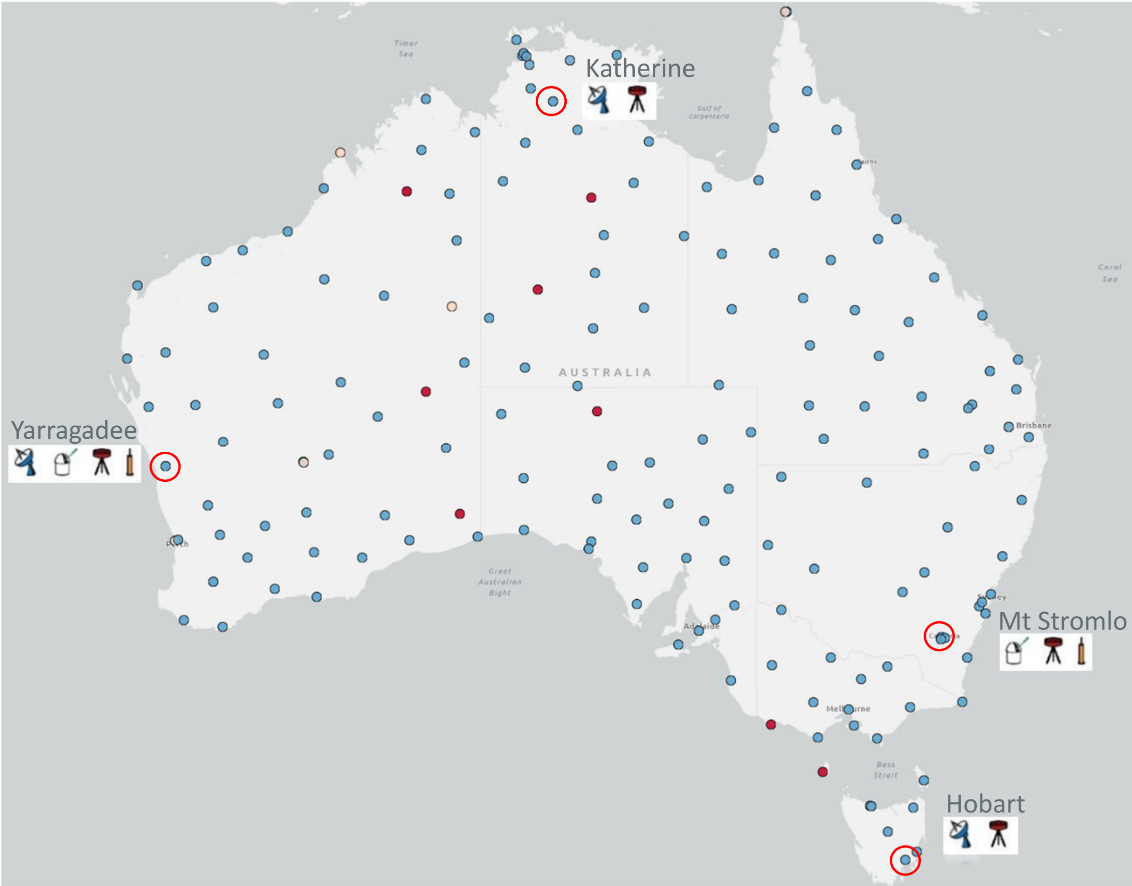


- The International Terrestrial Reference Frame (ITRF) Realisations are the combination of the four space geodetic techniques that are part of the Global Geodetic Supply Chain
    - Satellite Laser Ranging (SLR)
    - Global Navigation Satellite Systems (GNSS)
    - Doppler Orbitography Radio-positioning by Satellite (DORIS)
    - Very Long Baseline Interferometry (VLBI)

    - Co-locating these techniques allows for their combination

No matter how accurate the individual techniques are, a ground survey ties them all together

Domestic Co-Located Geodetic Observatories



TOTAL: 20 CO-LOCATED FEATURES

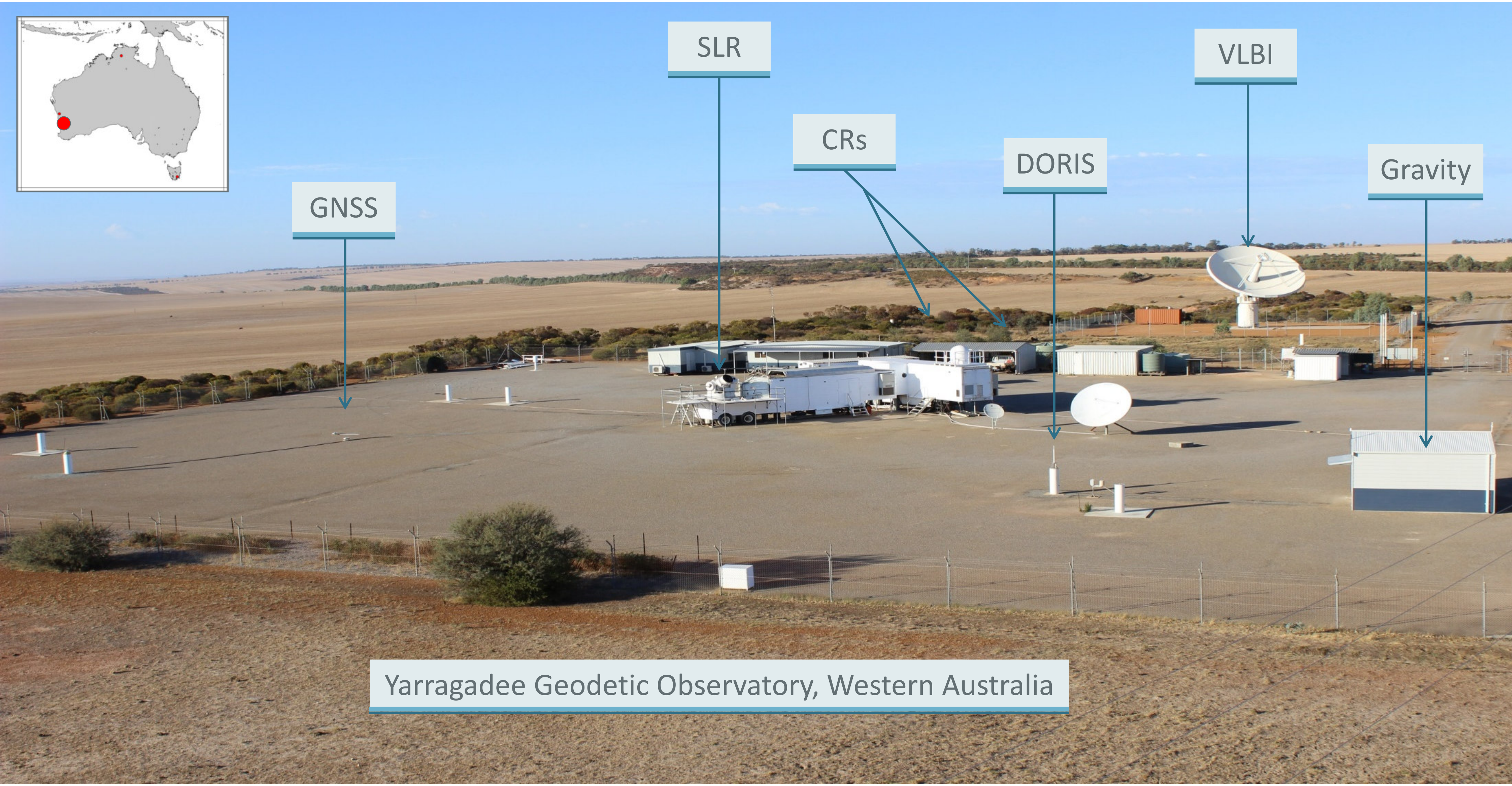
Yarragadee, WA
- 12m VLBI Radio Telescope (AuScope)
- Satellite Laser Ranging Telescope
- GNSS (x 3)
- DORIS
- Gravity BM

Mt Stromlo, ACT
- Satellite Laser Ranging Telescope
- GNSS (x 3)
- DORIS
- Gravity BM

Katherine, NT
- 12m VLBI Radio Telescope (AuScope)
- GNSS (x 2)

Hobart, TAS
- 12m VLBI Radio Telescope (AuScope)
- 26m VLBI Radio Telescope
- GNSS (x 1)
- Gravity BM

(https://gnss.ga.gov.au/)



SLR
VLBI
CRs
DORIS
Gravity
GNSS
Yarragadee Geodetic Observatory, Western Australia

GA Local Tie program

- 2023
  - Re-development of the capacity & plan to provide an updated set of results
  - Re-engagement with the international and educational communities, and local stakeholders of each site.
  - Review/modernisation of the technique to align with available resourcing, hardware, and software limitations, for sustainable continuation of the program
  - Maintenance and Calibration of equipment from the **AuScope Australian Geophysical Observing System (AGOS)**[1] pool of Geospatial Equipment, required to complete the survey
  - Publication of recent outstanding reports (**Mt Stromlo 2014, & 2018**)
  - Observation of **Hobart Site** and test / re-discover the established process

- 2024
  - Observation of **Mt Stromlo, Yarragadee & Katherine**, and further refinement of the process
  - Improved balance of WHS considerations in the observation process.
  - Refinement of the process and establish the future direction of the program
  - Publication of 2024 Reports

AuScope

[1]https://www.auscope.org.au/geodesy

A Quick Summary of Why and How…

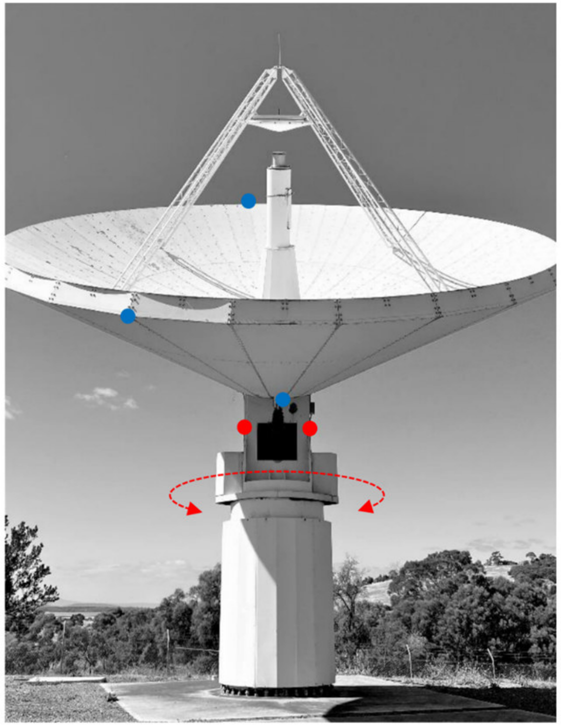


Figure 3.2.2.1 Primary Azimuth Axis

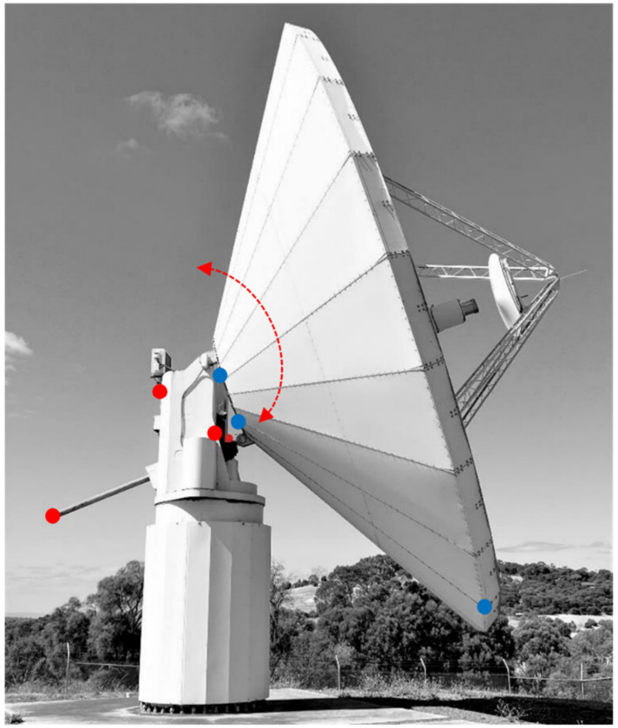
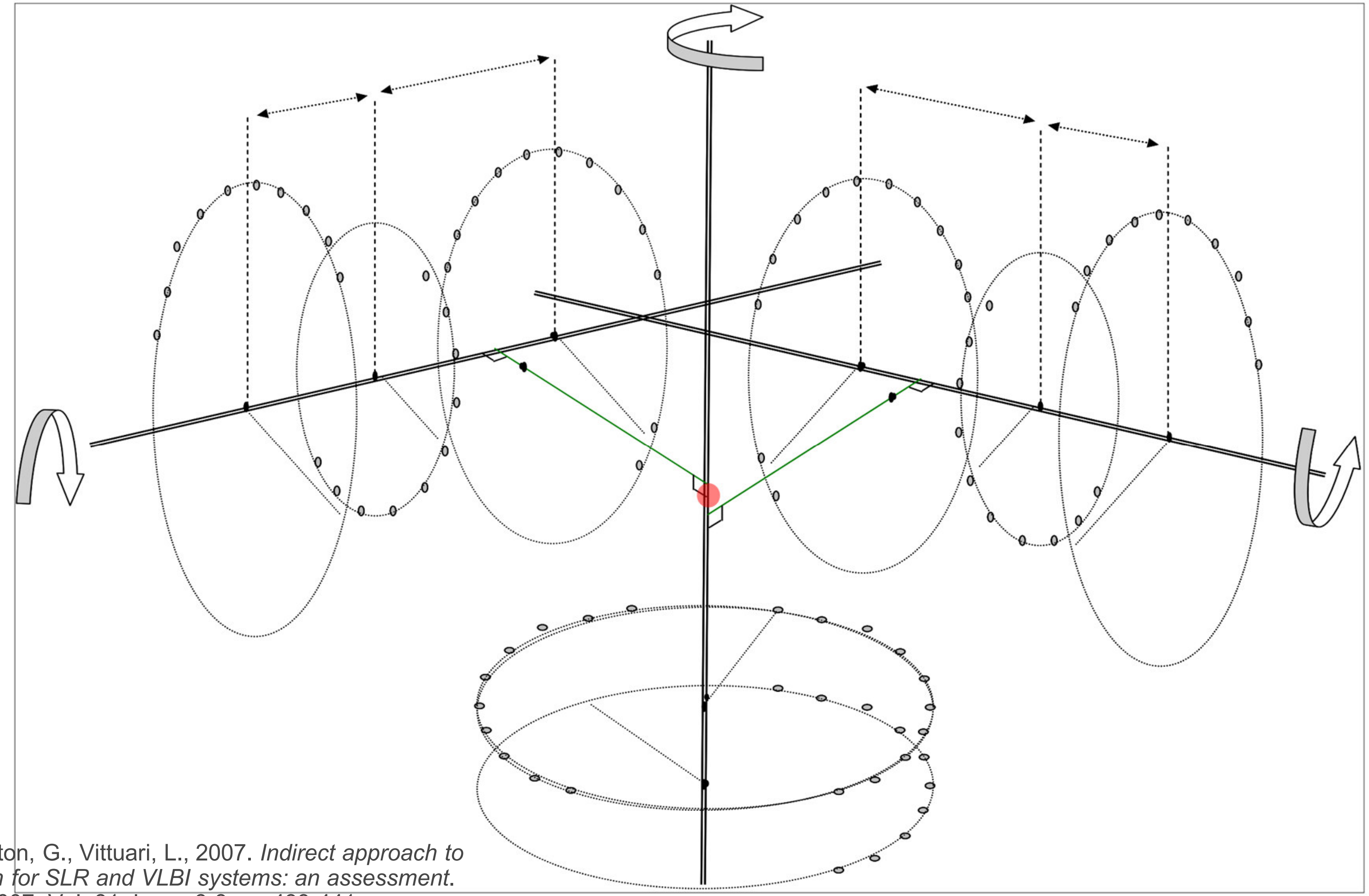


Figure 3.2.2.2 Secondary Elevation Axis

A Quick Summary of Why and How…



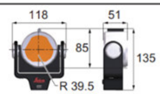
Dawson, J., Sarti, P., Johnston, G., Vittuari, L., 2007. *Indirect approach to invariant point determination for SLR and VLBI systems: an assessment*. Journal of Geodesy. June 2007, Vol. 81, Issue 6-8. pp 433-441.

The Established Survey Method:

1. Full survey network observation
    1. Orientation
    2. Levelling survey
    3. Horizontal angles
2. Most accurate equipment
3. Best practice measurements
    1. ICSM SP1 – Guideline for Conventional Traverse Surveys v2.2
4. High number of observations on telescope (rotation and targets)
    1. Time and Safety

What Can we improve?

Time, Safety, Complexity, Consistency?

Prism	Constant [mm]	Centring Accuracy [mm]	Dimensions [mm]
GPH1P Circular Prism	0.0	0.3	

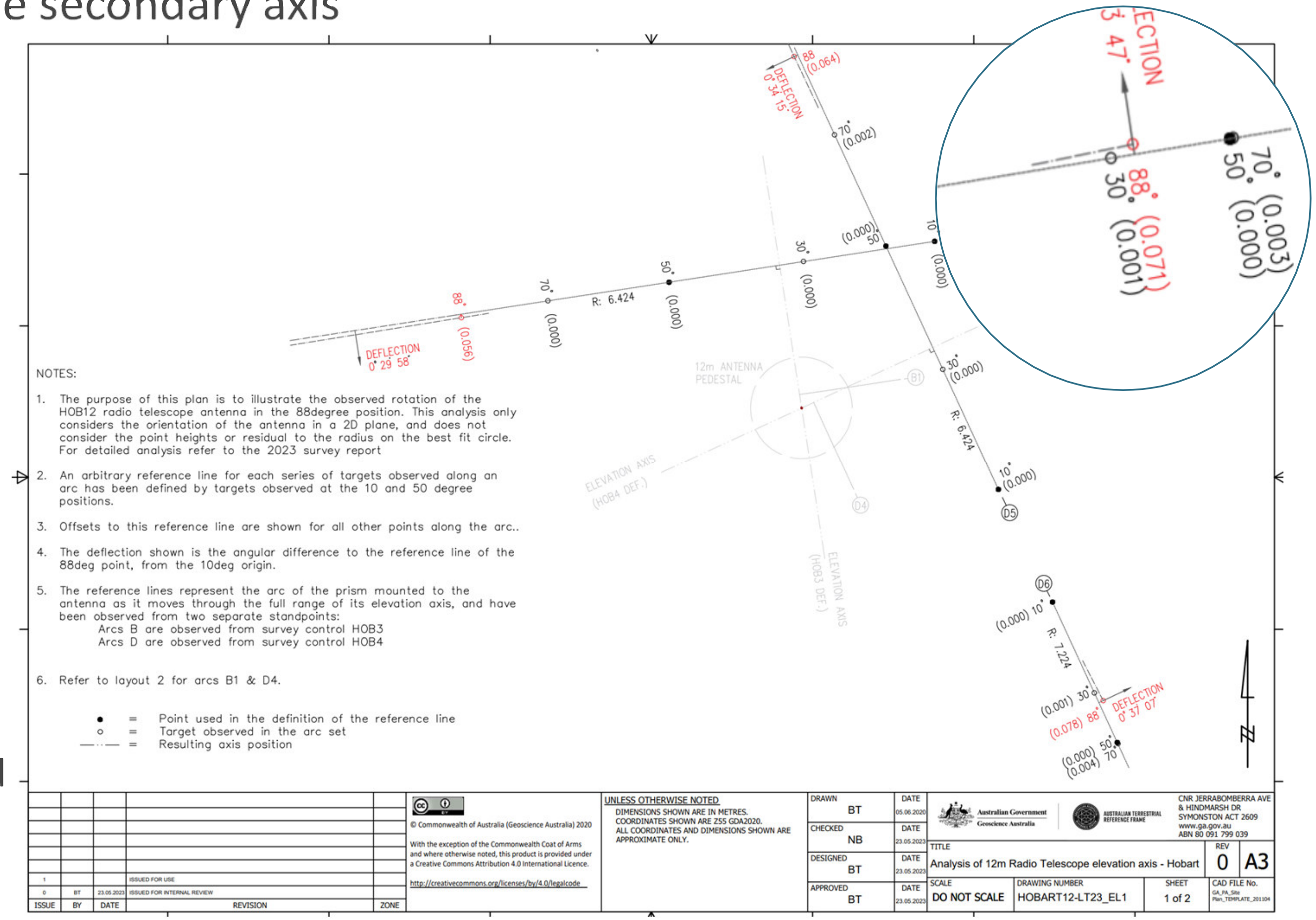
Discovering what we don’t know:

Detecting movement in the motion of the secondary axis

- Solution showing large residuals in circle fit
- Further analysis showed the issue was in the higher elevation obs.
- Mechanical failure was ruled out

Outcome:

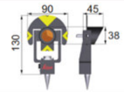
- The source was determined to be a calibration model applied to the pointing of the antenna
- The effect was observed in unresolved data from a previous survey
- Identified a need for better recording of the survey methodology
- The method to move the antenna was changed to ‘maintenance mode’
    - Development of SOP’s.

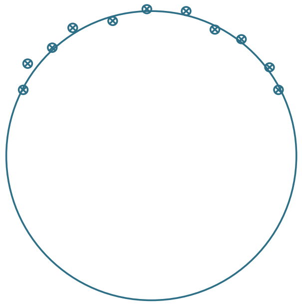


Refining the Survey Method:

SAFETY:

- Use of 360 prism to reduce re-pointing and the number of times elevated to height
  - Over a working distance of <50m
  - RMS & Mean residual to circle fit are indistinguishable.
- Use of light weight Tooling Ball prisms to remove personnel from SLR telescope altogether
- Both have benefits of **SAFETY & TIME** improvement
  - Faster Setup & observation sequence
  - Less manual pointing
  - More data points observed as a result

Prism	Constant [mm]	Centring Accuracy [mm]	Dimensions [mm]
GMP101 MiniPrism	+17.5	1.0	
GRZ101 360° MiniPrism	+30.0	1.5	



In Plane

Out of Plane

Azimuth Axis Circle Fit Residuals (mm)								
GMP101	Prism/Circle	W1	W2	W3	Y1	Y2	Y3	*Average*
(Yarragadee)	**In Plane RMS**	**0.7**	**0.3**	**0.6**	**0.6**	**0.4**	**0.4**	***0.5***
	In Plane Mean	0.2	0.1	0.3	0.0	0.2	0.2	
GRZ101	Prism/Circle	A7	A8	A9	C7	C8	C9	
(Katherine)	**In Plane RMS**	**0.5**	**0.8**	**0.5**	**0.5**	**0.8**	**0.6**	***0.6***
	In Plane Mean	-0.3	-0.2	0.3	0.2	0.2	0.0	
	Average In Plane RMS Difference							**0.1**

Azimuth Axis Circle Fit Residuals (mm)								
GMP101	Prism/Circle	W1	W2	W3	Y1	Y2	Y3	*Average*
Yarragadee	**Out of Plane RMS**	**0.2**	**0.2**	**0.5**	**0.2**	**0.2**	**0.2**	***0.2***
	Out of Plane Mean	0.0	0.0	0.0	0.0	0.0	0.0	
GRZ101	Prism/Circle	A7	A8	A9	C7	C8	C9	
Katherine	**Out of Plane RMS**	**0.8**	**1.1**	**0.8**	**1.0**	**0.9**	**0.9**	***0.9***
	Out of Plane Mean	0.0	-0.1	0.0	0.0	0.0	0.0	
	Average Out of Plane RMS Difference							**0.7**

Reducing Complexity - The Mt Stromlo Local Example

Assumptions:

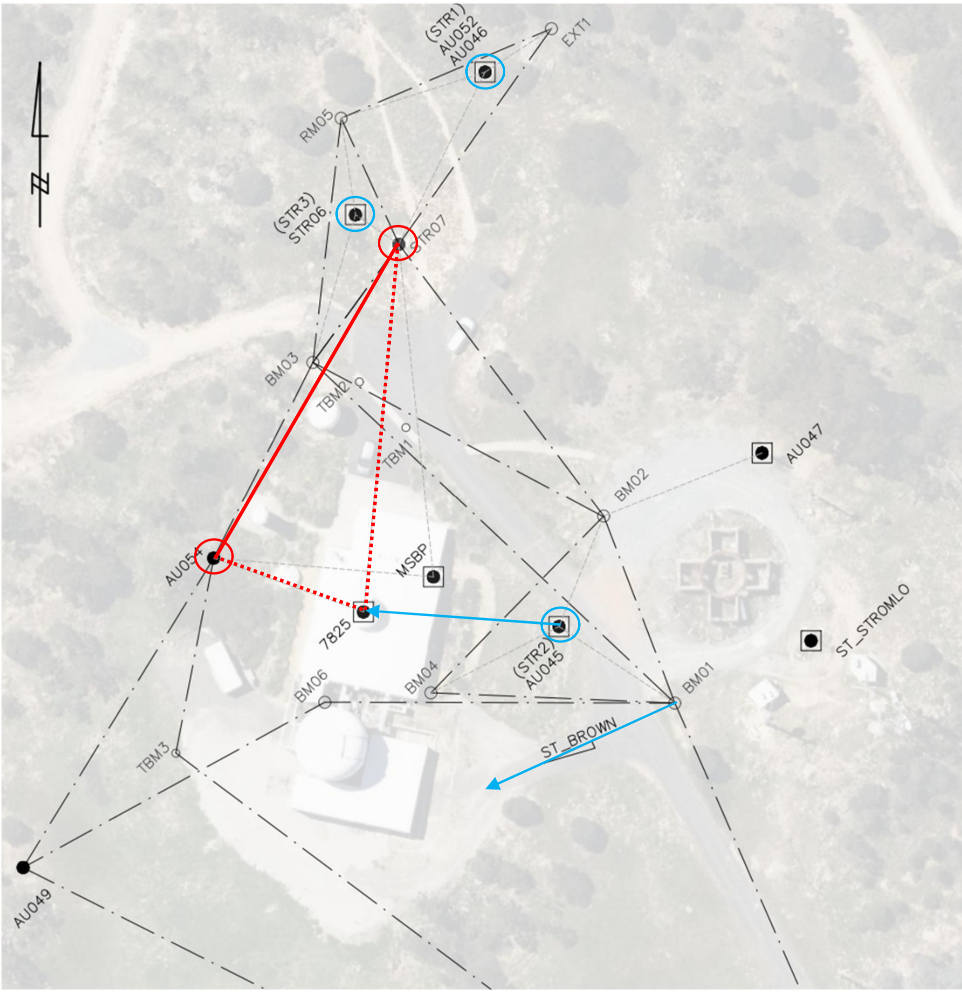
- Survey control is rigid (only observe from established control)
- GNSS CORS are on stable monuments, self monitoring & have been omitted from this survey.
- Absolute position and orientation were previously defined.

Outcome

- Deformation monitoring for the SLR telescope
- Develop a safe and adequate methodology
  - Protect the personnel by removing during observation
  - Protect the SLR equipment
- Compare to the more rigorous result obtained in 2024

Local Topocentric Coordinate System

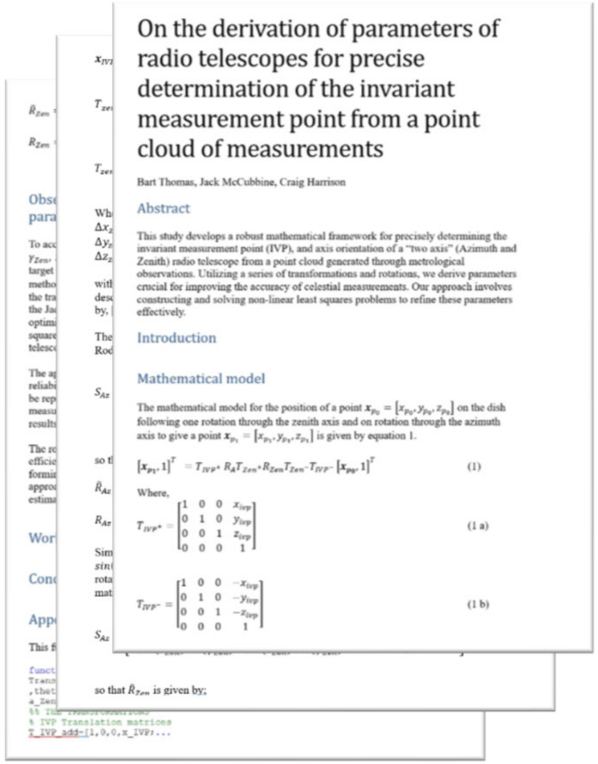
	Origin		IVP	^e	^n	^u
2024	AU45	:	7825	-24.9525	2.0070	2.4953
2025	AU45	:	7825	-24.9536	2.0069	2.4962
				-0.0011	**-0.0001**	**0.0009**



Conclusion & Future direction of local tie surveys by Geoscience Australia

Adopting these findings:

- Local Tie Surveys can be completed more consistently with less resources and time required
  - Leading to a more sustainable work program and regular results
- Major effort in the full site survey can be reduced in frequency or ‘as required’ (ITRF contribution)
  - Validation surveys could be completed between these epochs
- Simplified methodology could reduce effort further by;
  - Training local staff at the observatories to complete the measurements
  - Contracting the work out to local Surveyors.
  - Installing semi-permanent targets, mounts or equipment
- Development of a Point Cloud Observation Methodology
  - Potentially could derive a solution for telescope IVP from normal operation
  - Step towards automation?
- External stakeholder engagement
  - Interest from Universities in the methodology for a teaching resource
  - A demonstration of practical geodesy techniques to generate interest of Geodesy as a career path for spatial science



On the derivation of parameters of radio telescopes for precise determination of the invariant measurement point from a point cloud of measurements

Bart Thomas, Jack McCubbine, Craig Harrison

Abstract

This study develops a robust mathematical framework for precisely determining the invariant measurement point (IVP), and axis orientation of a “two axis” (Azimuth and Zenith) radio telescope from a point cloud generated through metrological observations. Utilizing a series of transformations and rotations, we derive parameters crucial for improving the accuracy of celestial measurements. Our approach involves constructing and solving non-linear least squares problems to refine these parameters effectively.

Introduction

Mathematical model

The mathematical model for the position of a point $\mathbf{x}_{p_0} = [x_{p_0}, y_{p_0}, z_{p_0}]$ on the dish following one rotation through the zenith axis and on rotation through the azimuth axis to give a point $\mathbf{x}_{p_1} = [x_{p_1}, y_{p_1}, z_{p_1}]$ is given by equation 1.

$$[\mathbf{x}_{p_1}, 1]^T = T_{IVP^+} R_A T_{Zen^+} R_{Zen} T_{Zen^-} T_{IVP^-} [\mathbf{x}_{p_0}, 1]^T \quad (1)$$

Where,

$$T_{IVP^+} = \begin{bmatrix} 1 & 0 & 0 & x_{ivp} \\ 0 & 1 & 0 & y_{ivp} \\ 0 & 0 & 1 & z_{ivp} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1\text{ a})$$

$$T_{IVP^-} = \begin{bmatrix} 1 & 0 & 0 & -x_{ivp} \\ 0 & 1 & 0 & -y_{ivp} \\ 0 & 0 & 1 & -z_{ivp} \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1\text{ b})$$

so that $\hat{R}_{Zen}$ is given by;

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Thank You

Thanks also for the contribution and assistance of:

Craig Harrison, Renato Gonzalez, Jack McCubbine, Randall Carmen, Brett Reid (UTAS), Warren Hankey (UTAS), Boye Zhou (UTAS), Darryl Stacey (NTGS), Darryn Whelan (CDU), NT Survey Services, Jamie McCallum (UTAS), Lucia McCallum (UTAS), Christopher Watson (UTAS),

…who all helped make the latest survey campaign possible.

Bart Thomas | Geodetic Survey Coordinator
National Geodesy Section | Space Division

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The most relevant SDGs related to the presentation and theme of this session

1st relevant SDG

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

2nd relevant SDG

17 PARTNERSHIPS FOR THE GOALS

3rd relevant SDG

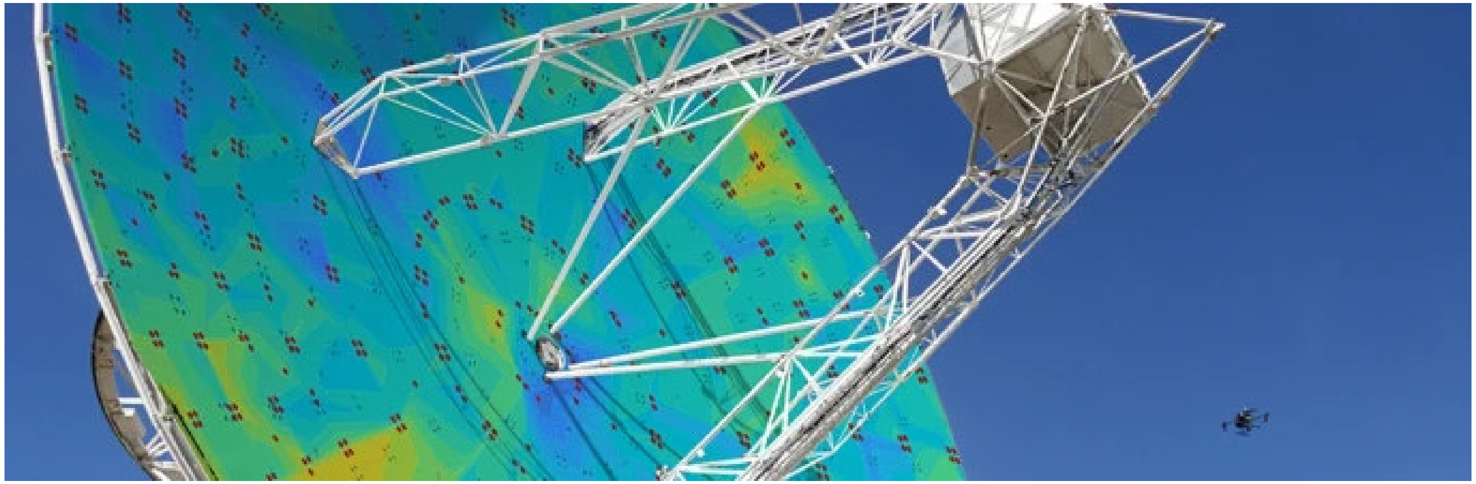
4 QUALITY EDUCATION

SUSTAINABLE DEVELOPMENT GOALS | International Federation of Surveyors supports the Sustainable Development Goals

A quick shout-out to some novel research:

Research into effect of gravity deformation on VLBI antenna

- 26-m radio telescope at the Mount Pleasant Radio Observatory Hobart (Tasmania, Australia)[1]



[1]Lösler, M., Eschelbach, C., Greiwe, A., Zhou, B., McCallum, L. Innovative approach for modelling gravity-induced signal path variations of VLBI radio telescopes. *Earth Planets Space* **77**, 9 (2025). https://doi.org/10.1186/s40623-024-02110-8