



Infrastructure update: South African Radio Astronomy Observatory



Pillar 3: Infrastructure

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Workshop 2 of the SAGWG, Tsitsikamma Building, DLRRD | 1 October 2026



Geodetic equipment at Hartebeesthoek

Radio Antennas:

- 26m
- 15m
- VGOS

Satellite Laser Rangers:

- MOBLAS6 (NASA)
- Sazhen-TM (ROSCOSMOS)

DORIS:

- At SANSA Space Ops

Global Navigation Satellite Systems Reference Stations:

- GPS: NASA (2)
- Galileo - ESA (1) and DLR (1)
- GLONASS: ROSCOSMOS (1)
- Beidou: CAS (1)

Other:

- Various meteo sensors
- Seismic equipment
- Meteorite monitor

Test-beds:

- HERA etc.

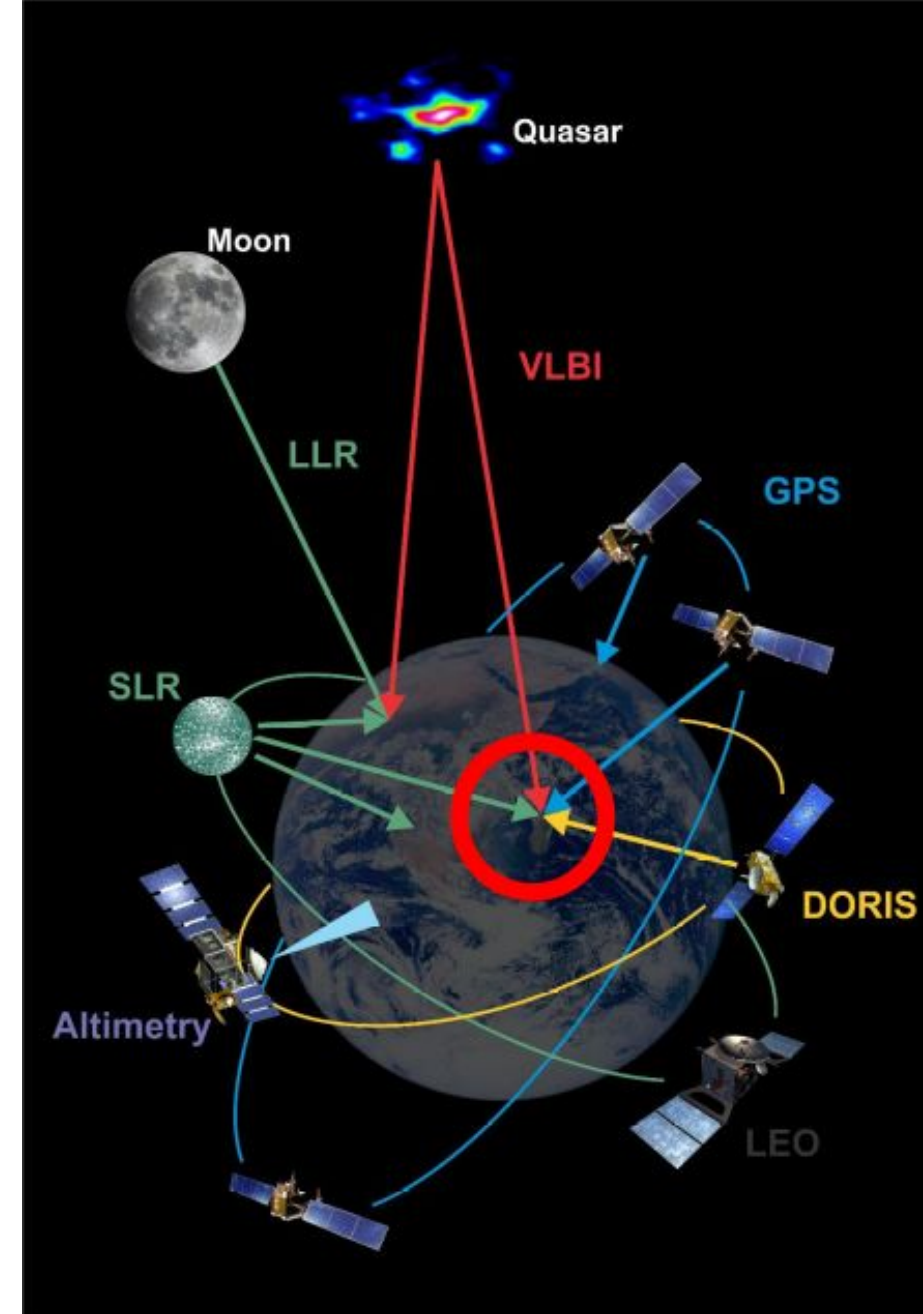
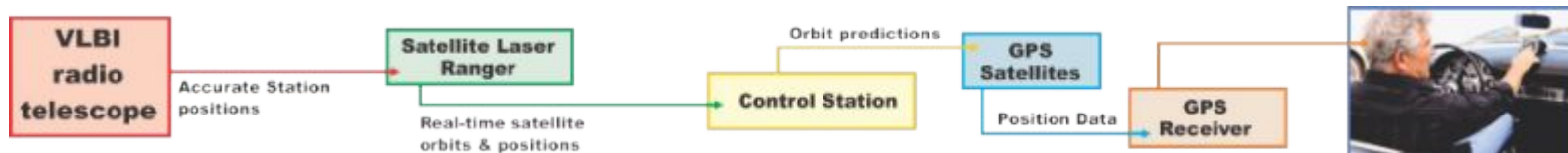
Photo credit: Jacoline
Schoonees/DIRCO

Geodetic equipment - Fundamental Site

- **Global Navigation Satellite Systems:**
 - Global Positioning System (GPS)
 - Global Orbiting Navigation Satellite System (GLONASS)
 - The European Navigational System (Galileo)
 - Chinese Satellite Navigational System “Compass” (Beidou)
- **Very Long Baseline Interferometry (VLBI)**
- **Laser Ranging to satellites and the Moon (SLR and LLR)**
- **Doppler Orbitography and Radio-positioning (DORIS)**
- Local automated Site-tie
- Geo-physical measurements: seismicity, gravity, meteorological data

These techniques are used both separately and in conjunction with each other in Space Geodesy

What makes it work? COLLOCATION



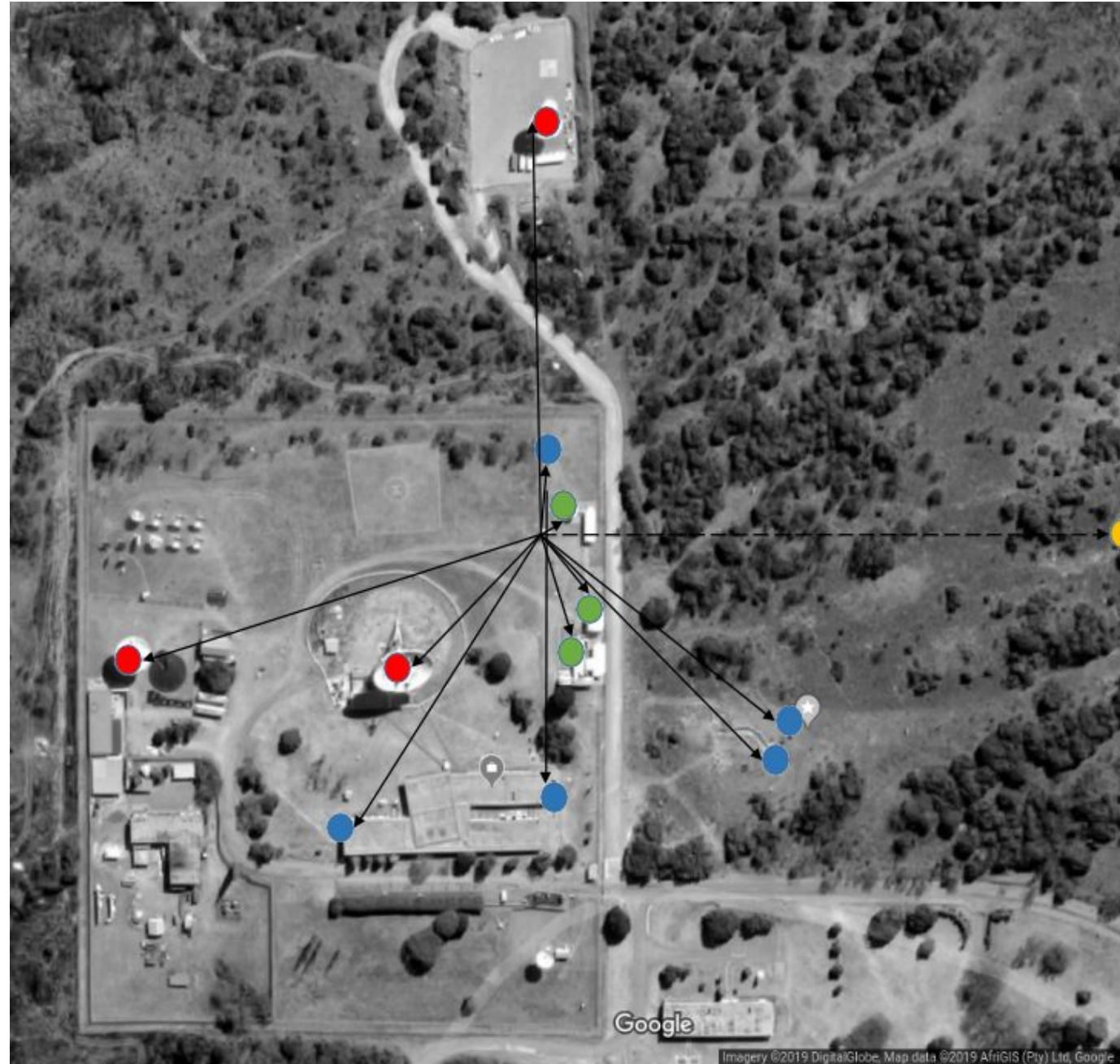
Fundamental Site - Site Tie

Site Tie

- Determine inter-instrumental vectors
- Serves as a terrestrial tie
- Compared to independent technique-determined reference positions



Leica MS50 total station
With at least a Leica GRZ4 360° prism and Leica GPH1P prism
on each major instrument on site



Geodetic equipment - Fundamental Site
Why collocation is important

Parameter type	VLBI	GPS/ GLON.	DORIS/ PRARE	SLR	LLR	Alti- metry
Quasar Coord. (ICRF)	X					
Nutation	X	(X)			X	
Pole Coord. X, Y	X	X	X	X	X	
UT1	X					
Length of day (LOD)		X	X	X	X	
Sub-daily ERPs	X	X				
ERP Amplitudes of ocean tides	X	X		X		X
Station Coord.+ Velocities (ITRF)	X	X	X	X	X	(X)
Geocenter		X	X	X		X
Gravity field		X	X	X	(X)	X
Satellite orbits		X	X	X	X	X
LEO orbit determination		X	X	X		X
Ionosphere	X	X	X			X
Troposphere	X	X	X			X
Time/Frequency transfer	(X)	X	X			

Where is the 'reference point'?

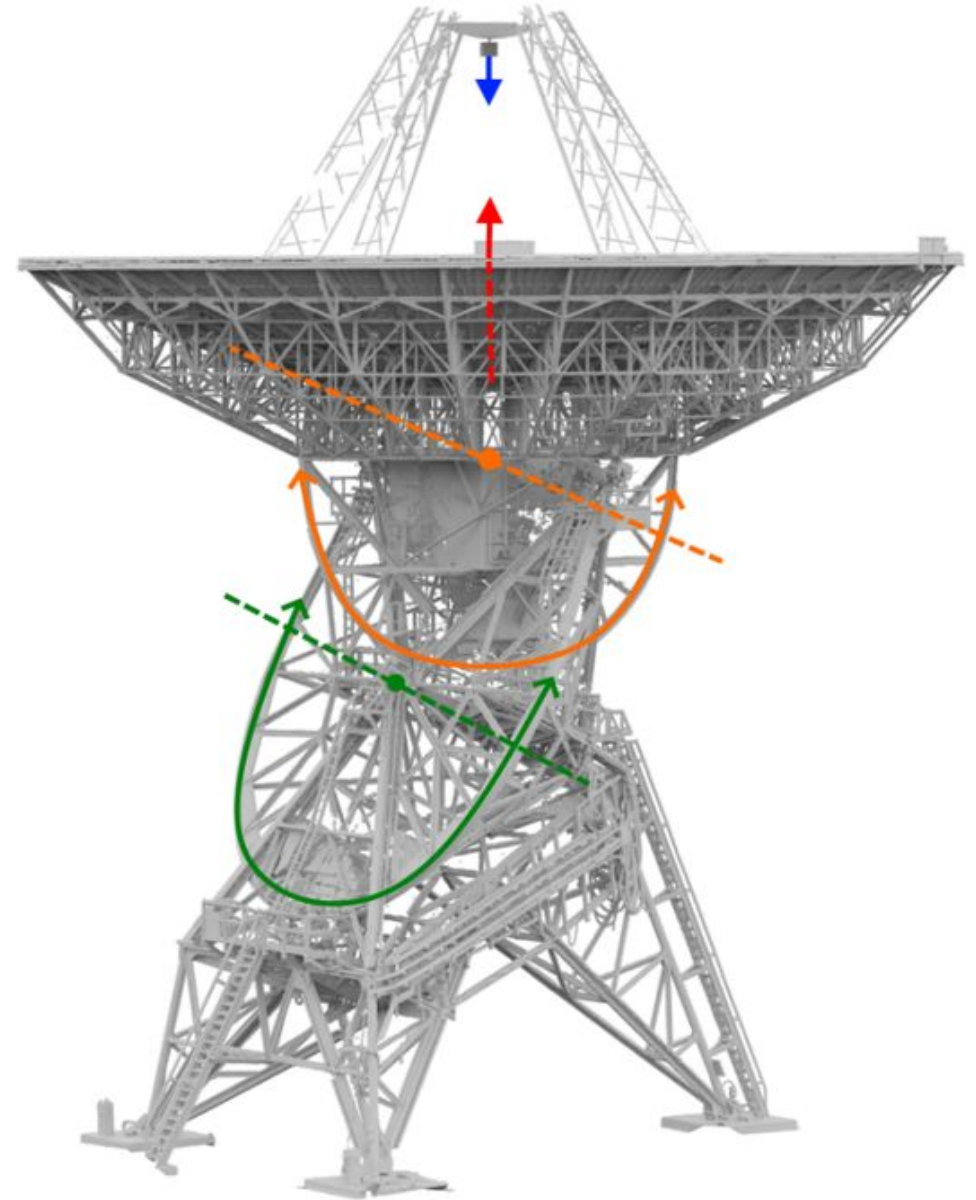
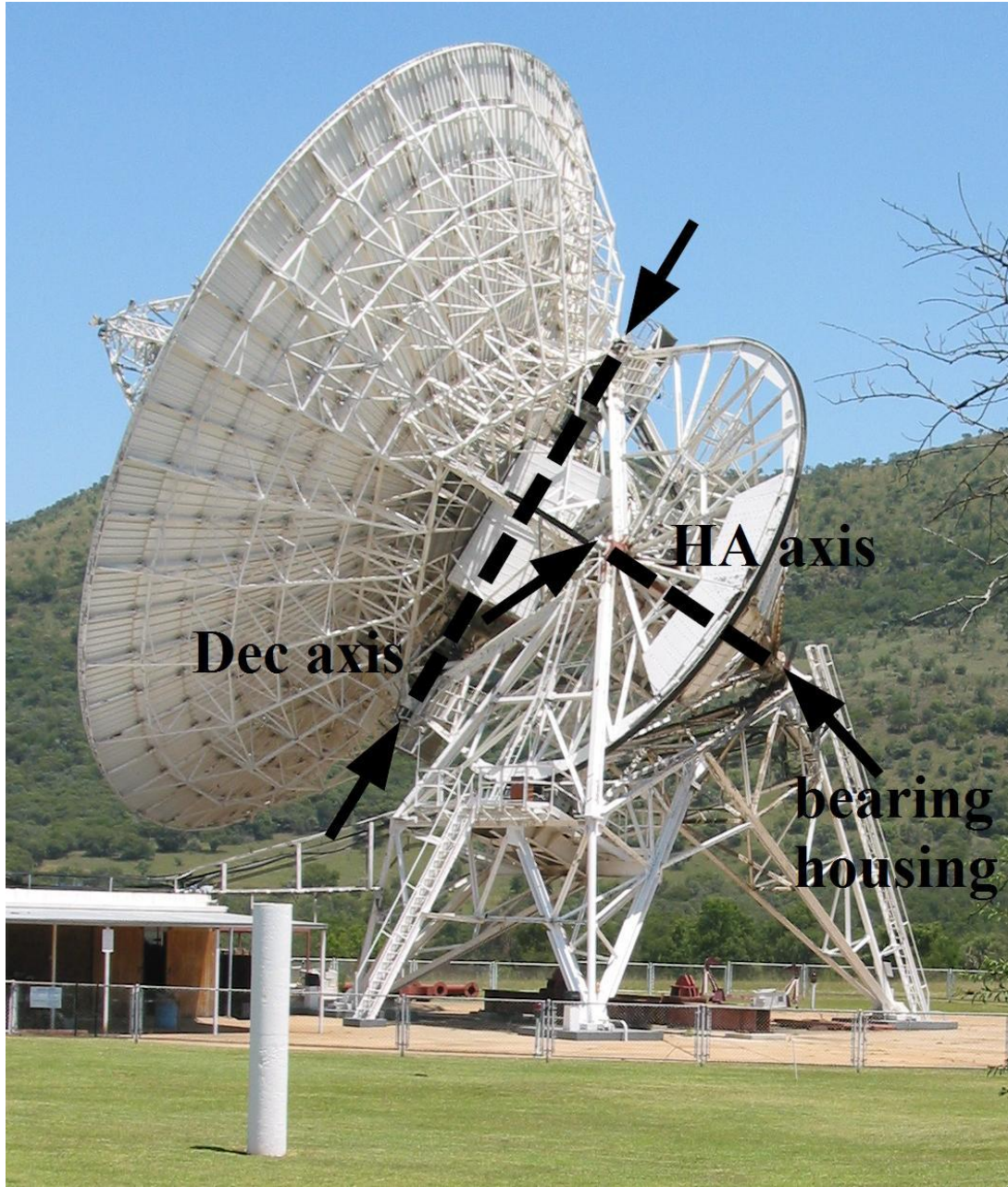
In geodesy and space-geodetic tracking, the **Antenna Invariant Point (IVP)**—also called the Geodetic Reference Point (GRP):

the absolute geometric reference point of a tracking antenna or telescope that remains perfectly fixed in three-dimensional space regardless of how the instrument rotates to track a target

For standard alt-azimuth tracking antennas (which rotate horizontally in azimuth and vertically in elevation), the IVP is geometrically defined by its rotational axes:

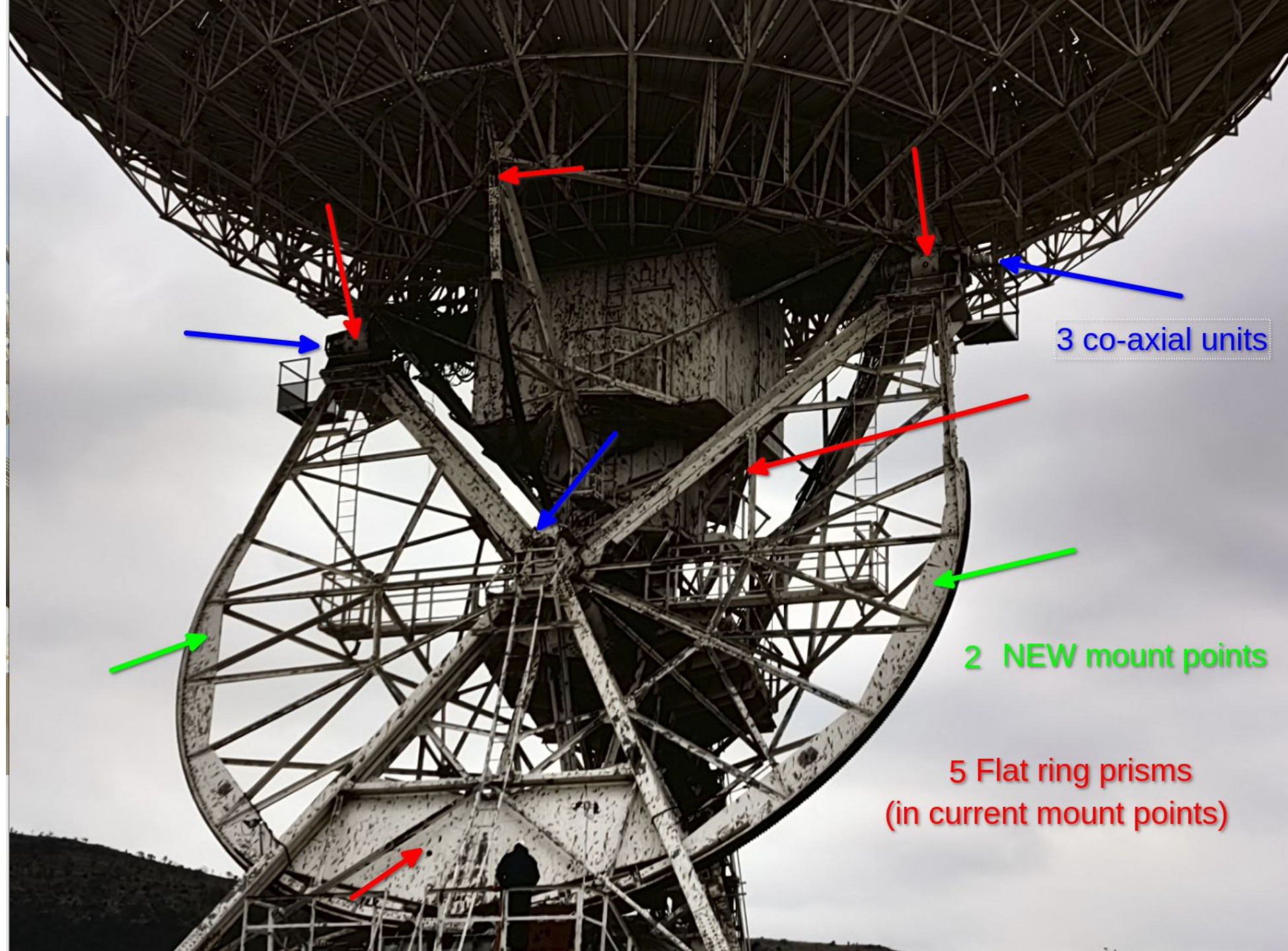
- Non-Intersecting Axes (Axis Offset): ***the orthogonal projection of the secondary (elevation / declination) axis onto the primary (azimuth / equatorial) axis.*** The physical gap between them is known as the axis offset.

Where is the 'reference point'?



Prisms...

Many
prisms...



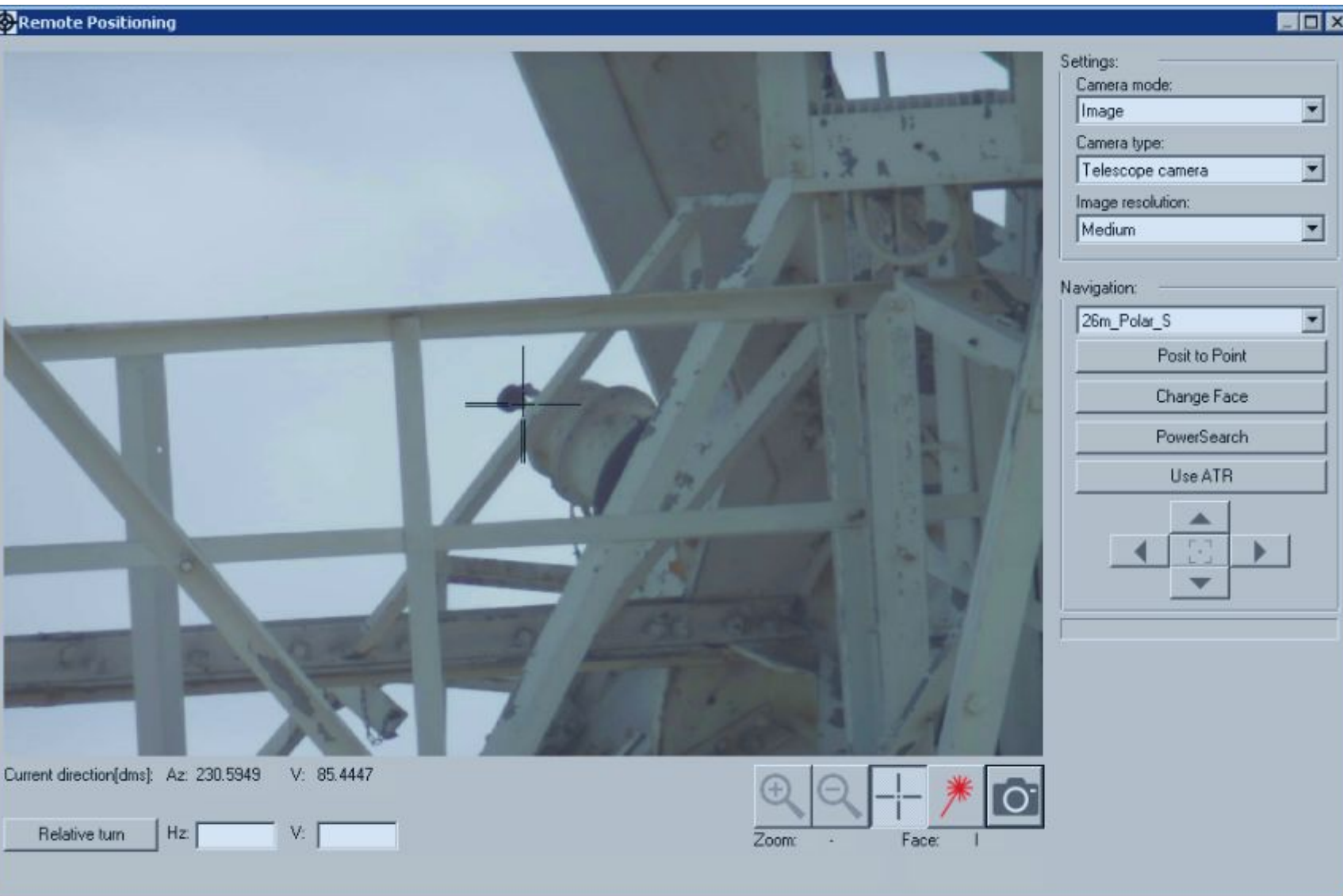
3 co-axial units

2 NEW mount points

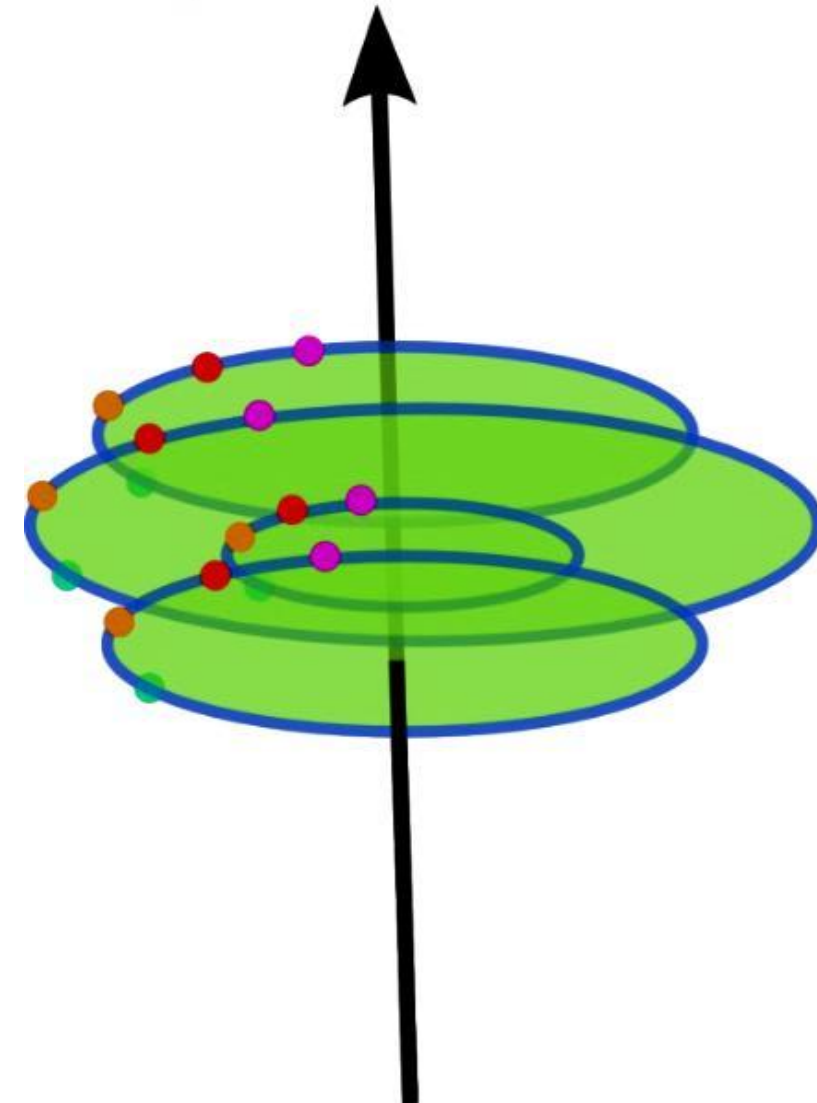
5 Flat ring prisms
(in current mount points)

Where is the reference point?

On-axis (co-axial) prisms

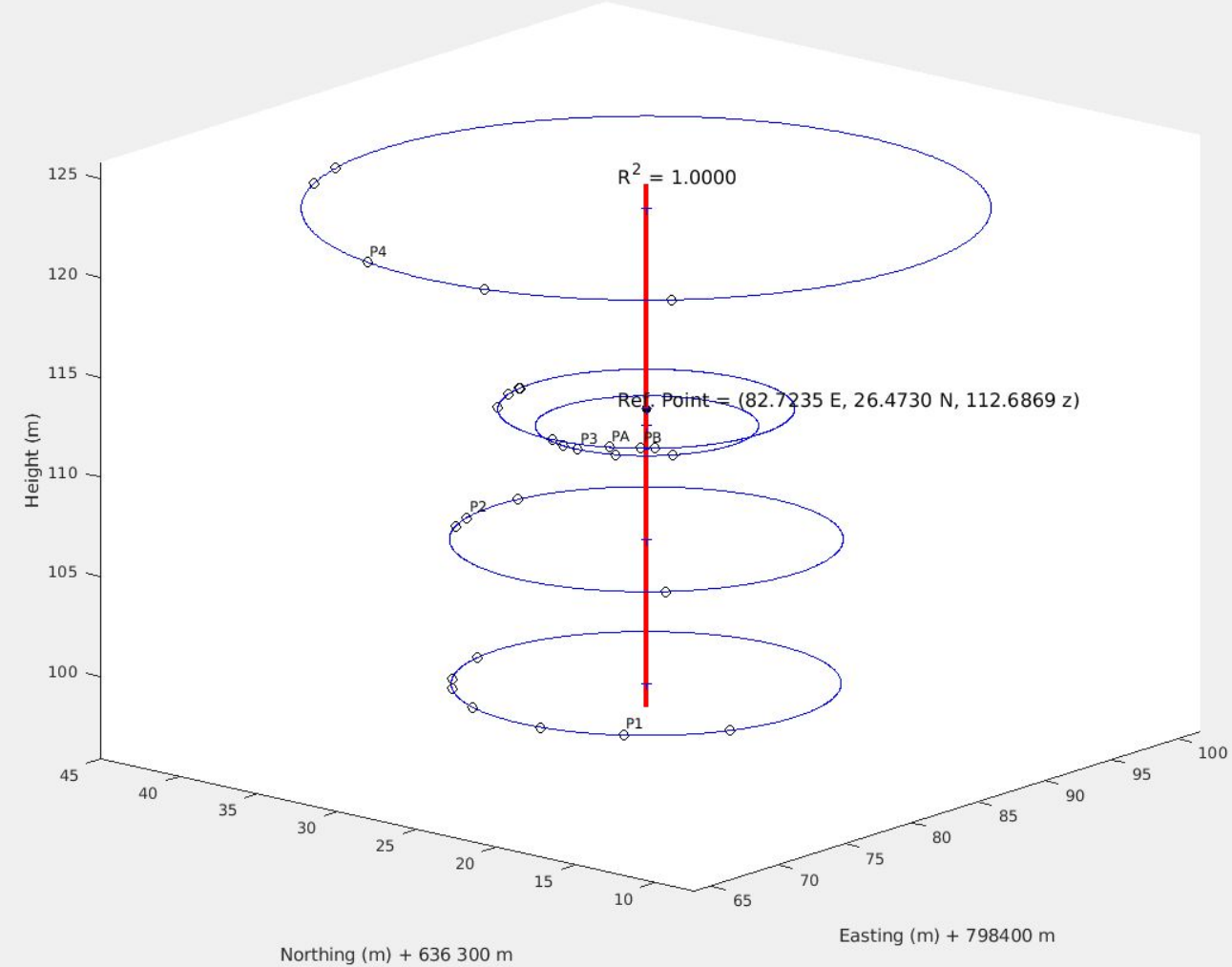


Off-axis prisms

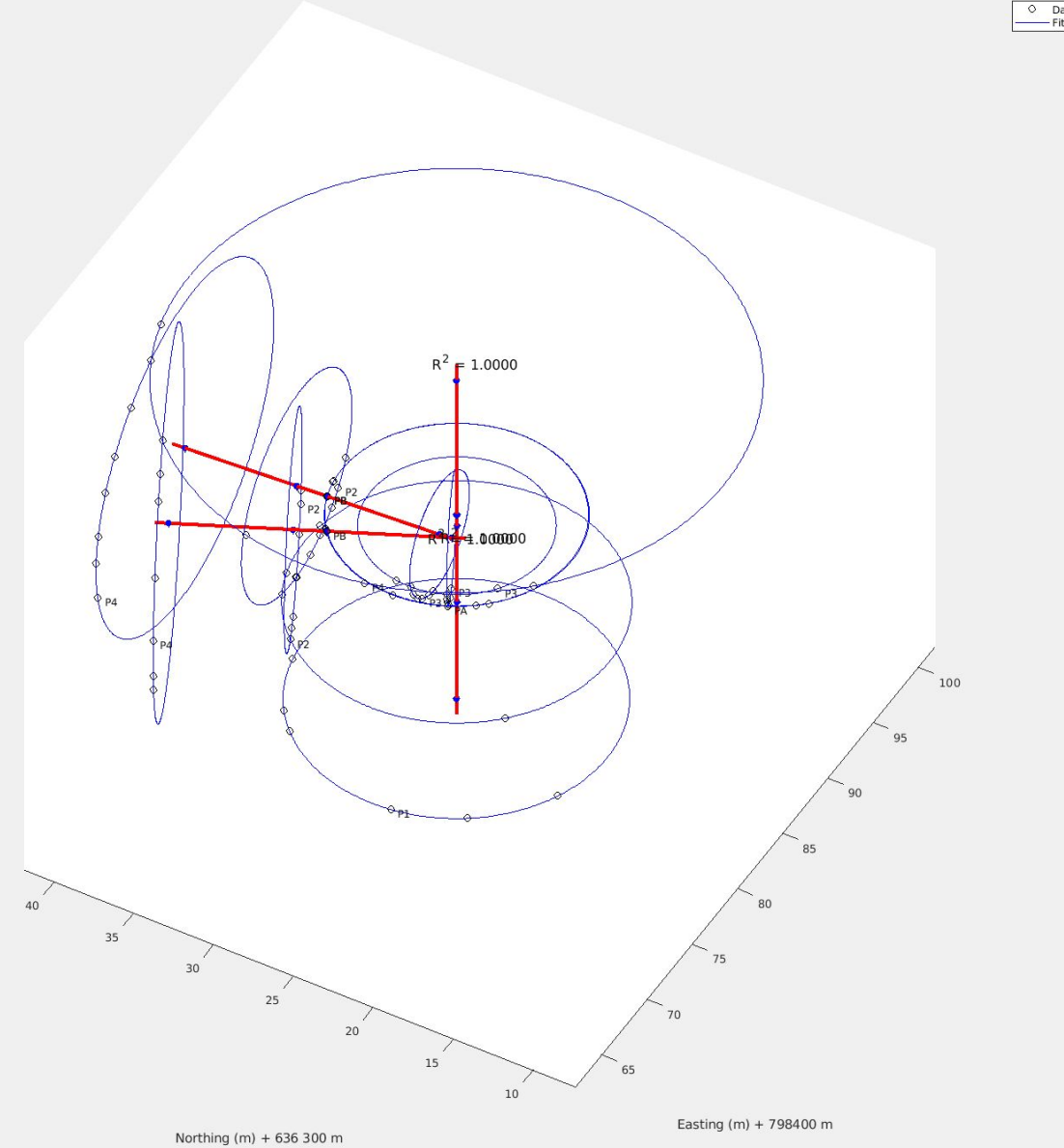


○ Data points
— Fit

Horizontal circles @ EI = 90d



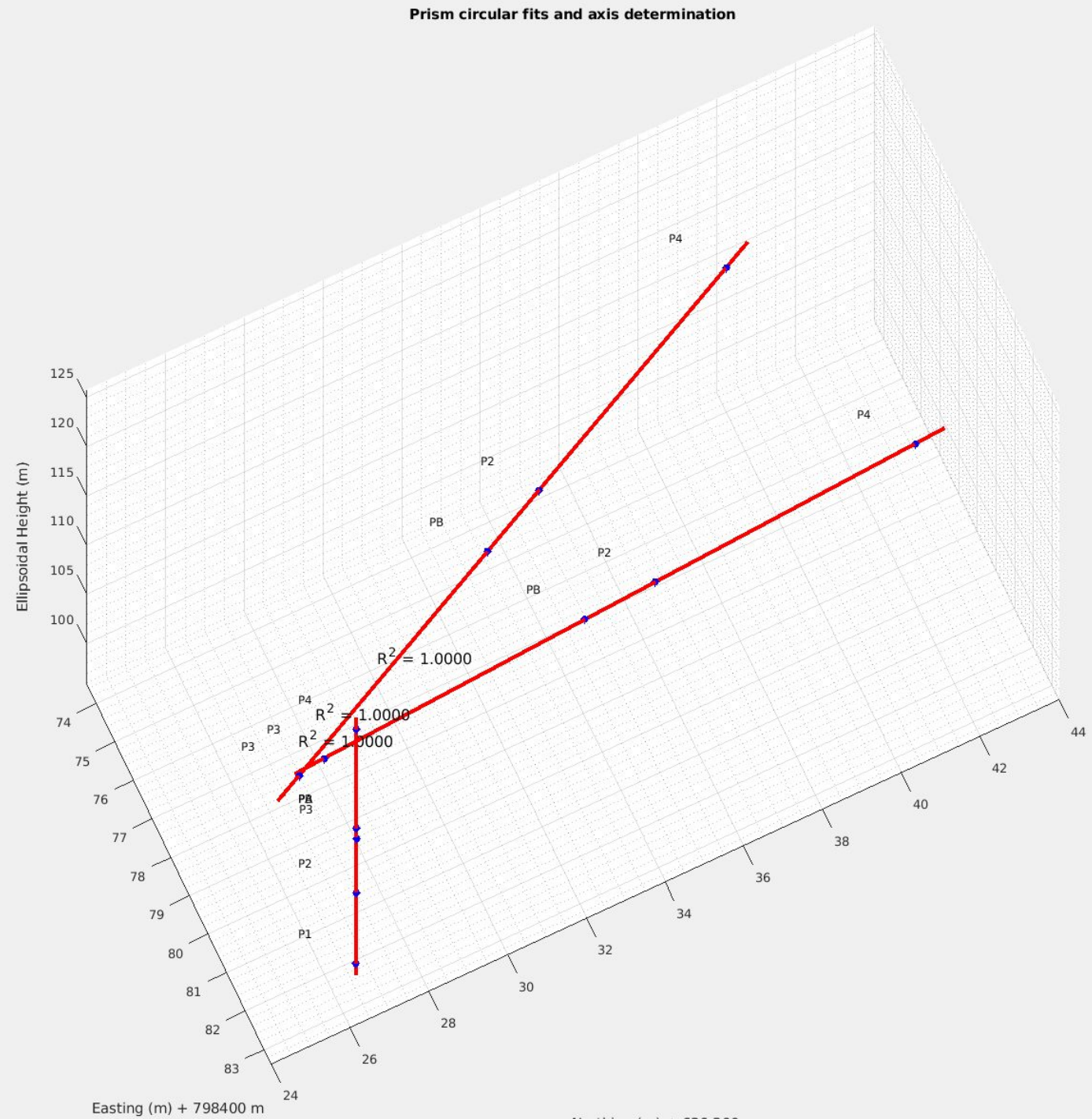
Prism circular fits and axis determination



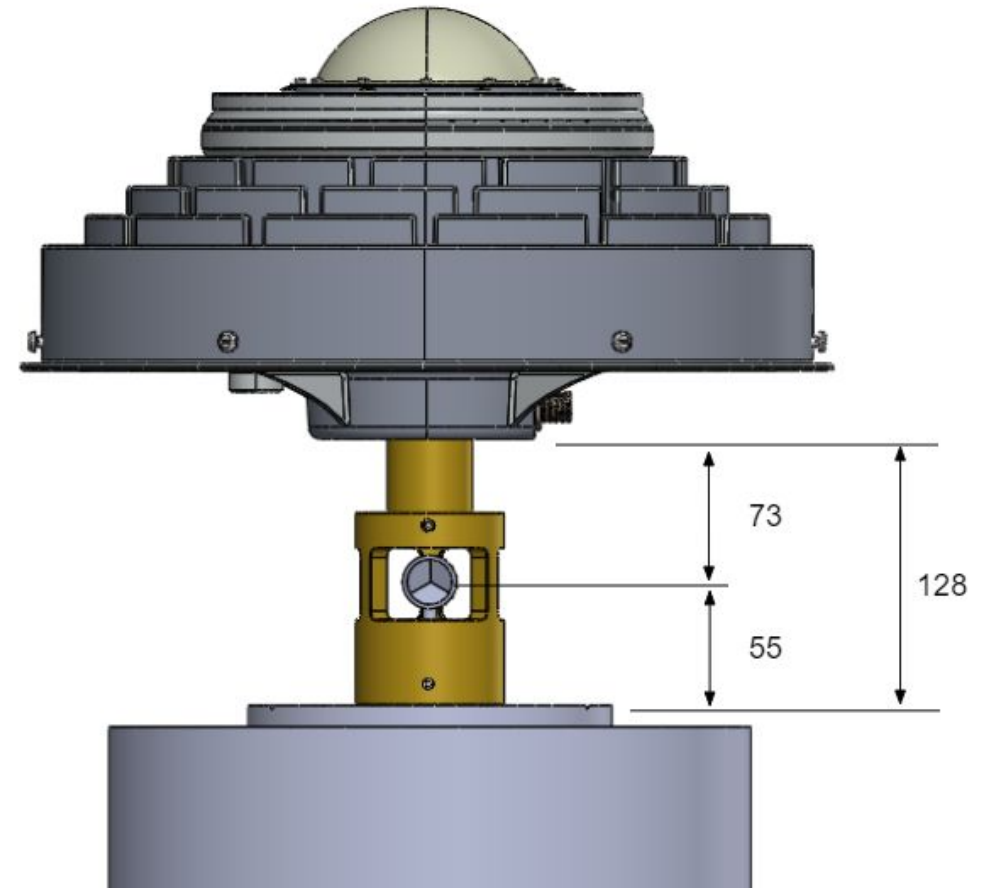
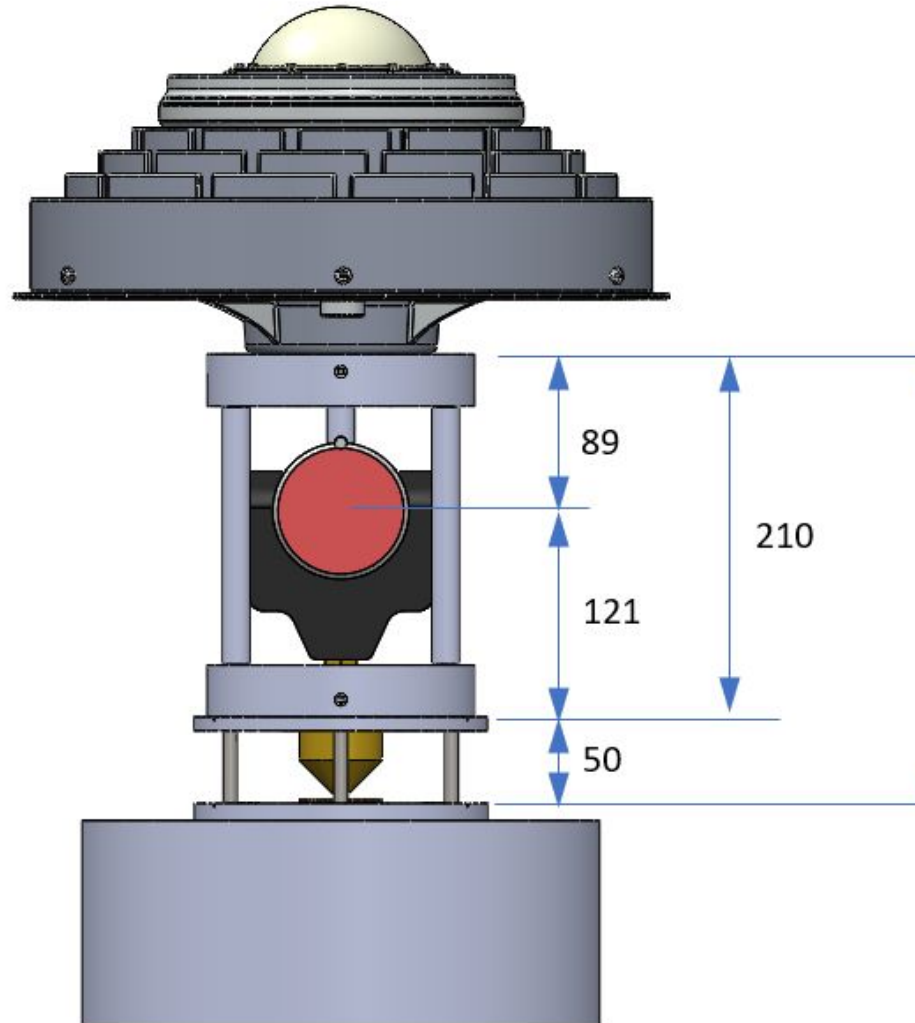
These are some initial results from the GRAO telescope, Ghana

Determine:

- axes
- planes
- intersections



Link to GNSS





(a)



(b)

Full site tie

... and then some more work, we still need to get to....



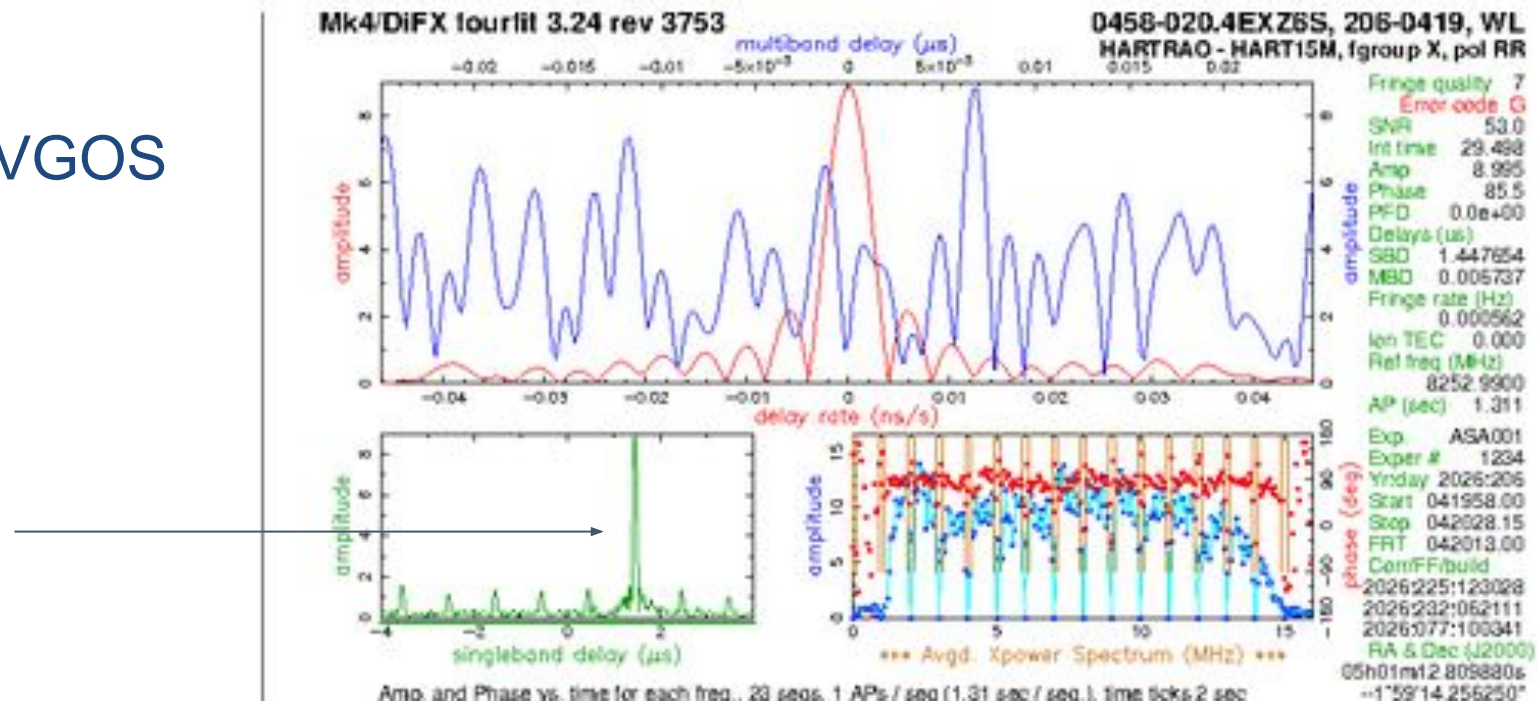
Geodetic VLBI Ops 2026

Instrument	Sessions
26 m (equatorial/polar) HARTRAO, Hh • X/S receiver (3.5/13 cm = 8.2/2.4 GHz)	• 30 IVS sessions (sessions requiring high sensitivity) • 6 K-band astrometric sessions - source structure and positions in SH • 6 local tie sessions
15 m (azel) HART15M, Ht • X/S receiver (3.5/13 cm = 8.2/2.4 GHz)	• 155 IVS sessions (legacy geodetic VLBI workhorse) • 6 local tie sessions
VGOS (azel) HARTVGS, Hv • VGOS broadband receiver (2-14 GHz)	• 54 IVS sessions (VGOS broadband sessions) • 6 local tie sessions

VLBI Research and Development 2026

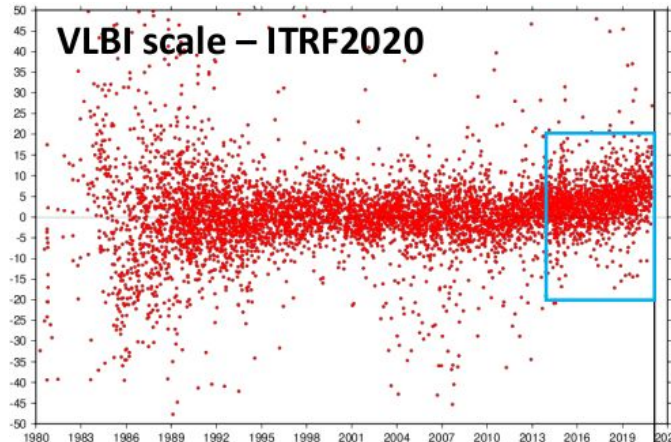
Collaboration with University of Tasmania, Hobart Observatory:

- We now have the skills to schedule Geodetic VLBI experiments: VieVS and VieSched++
- Correlation software system - our first working system has been set up in a Virtual Machine: DiFX and HOPS
- 15m instability study initiated
- Local Short BaseLine (SBL) was scheduled and observed for local VLBI tie, to be combined with results from Terrestrial tie system
- New Southern Intensives (SI) VGOS session in the pipeline

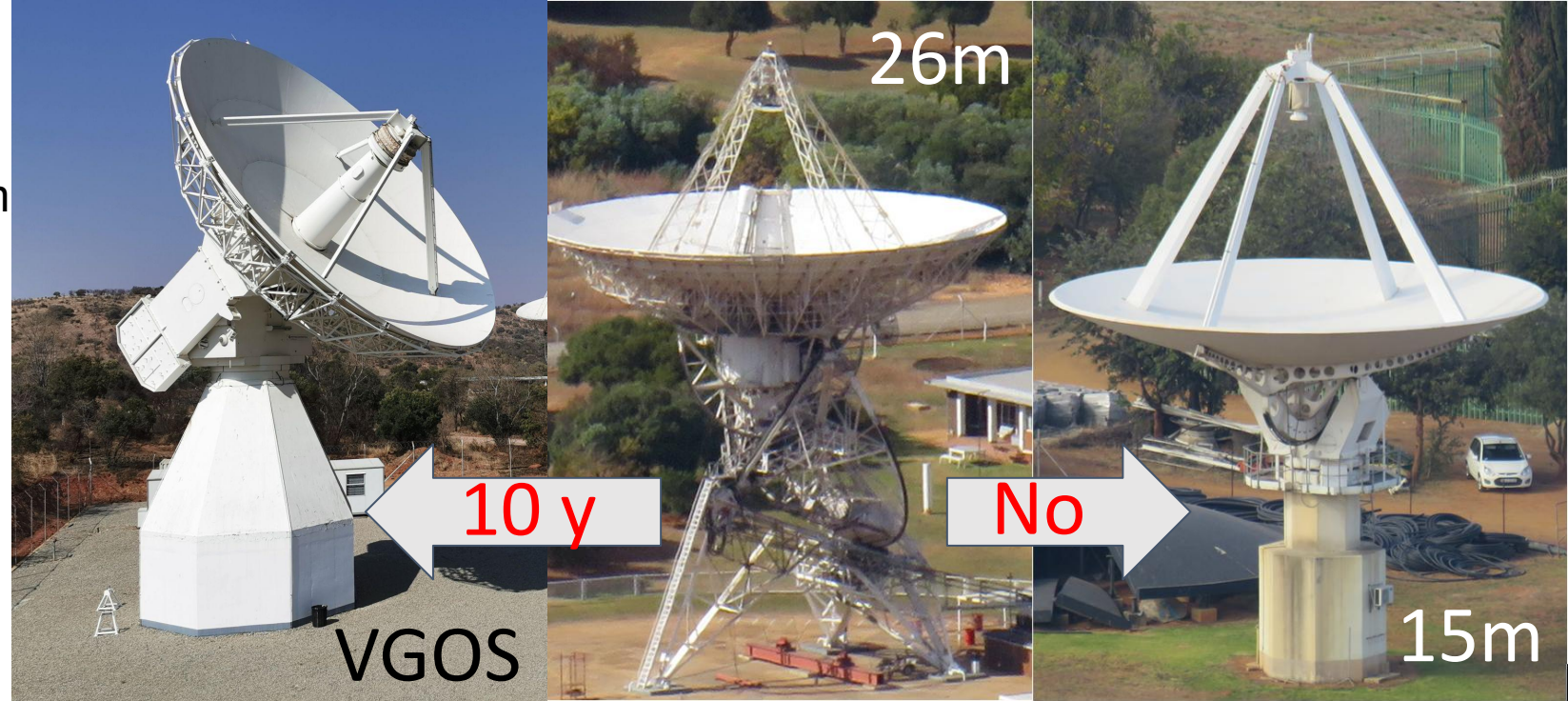


Hartebeesthoek94 Datum

1. Hart94 Datum (26m)
2. VLBI Scale problem: Determined 15m has stability issues -therefore not a viable reference



<https://doi.org/10.5281/zenodo.15304269>



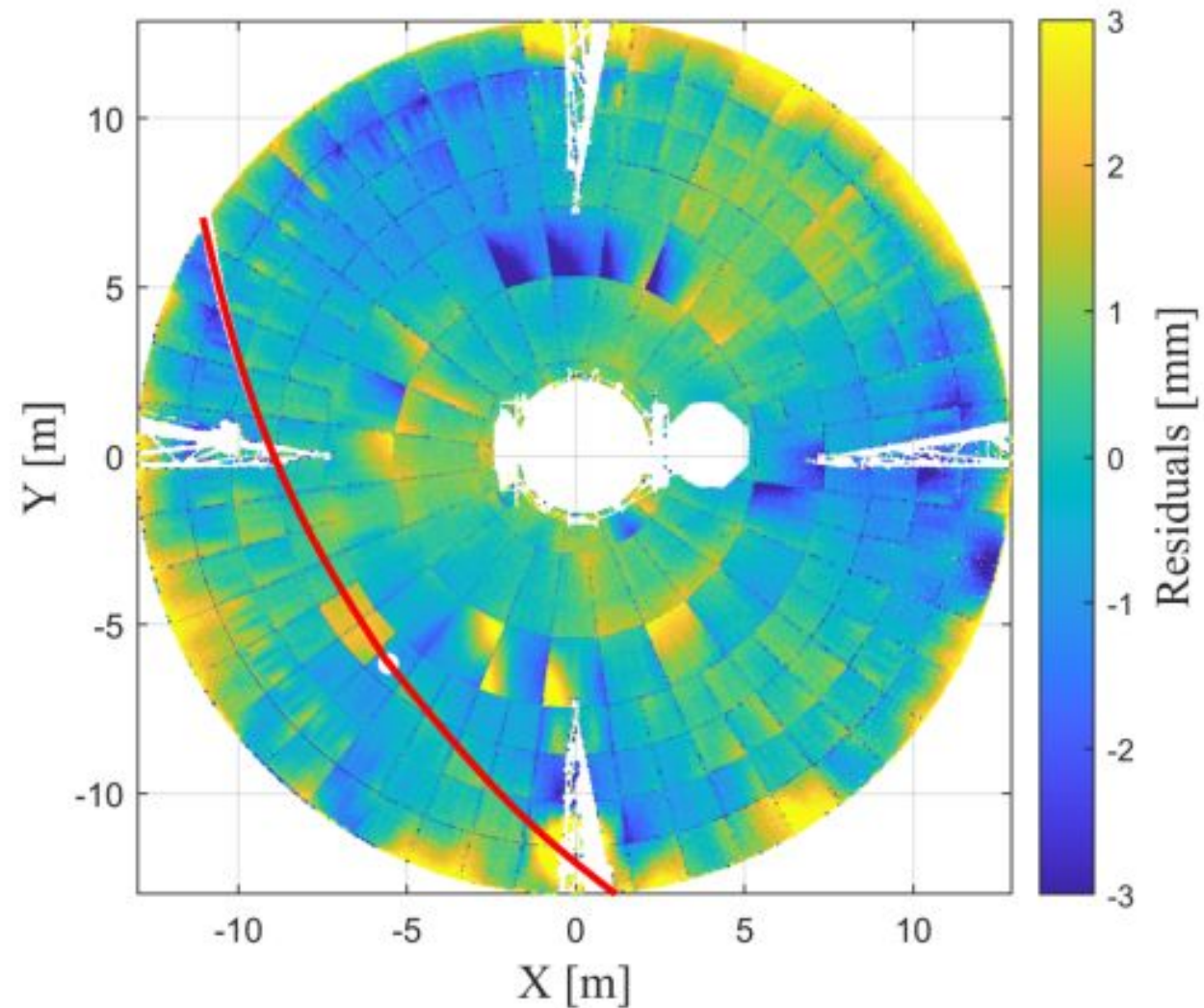
1. To transfer the reference from 26m to VGOS, 8.5 more years of parallel observation between 26m and VGOS required.

HART15M:

- ITRF2020 update data gap - 2016, doy 288;
- Non linearity - 2021, doy 001.

[illegible]

26m Gravitational Deformation Study



Geodetic equipment - remote stations

Network of remote stations / equipment:

- (Nearly) Always a GNSS station
- Collocation of various geodetic equipment

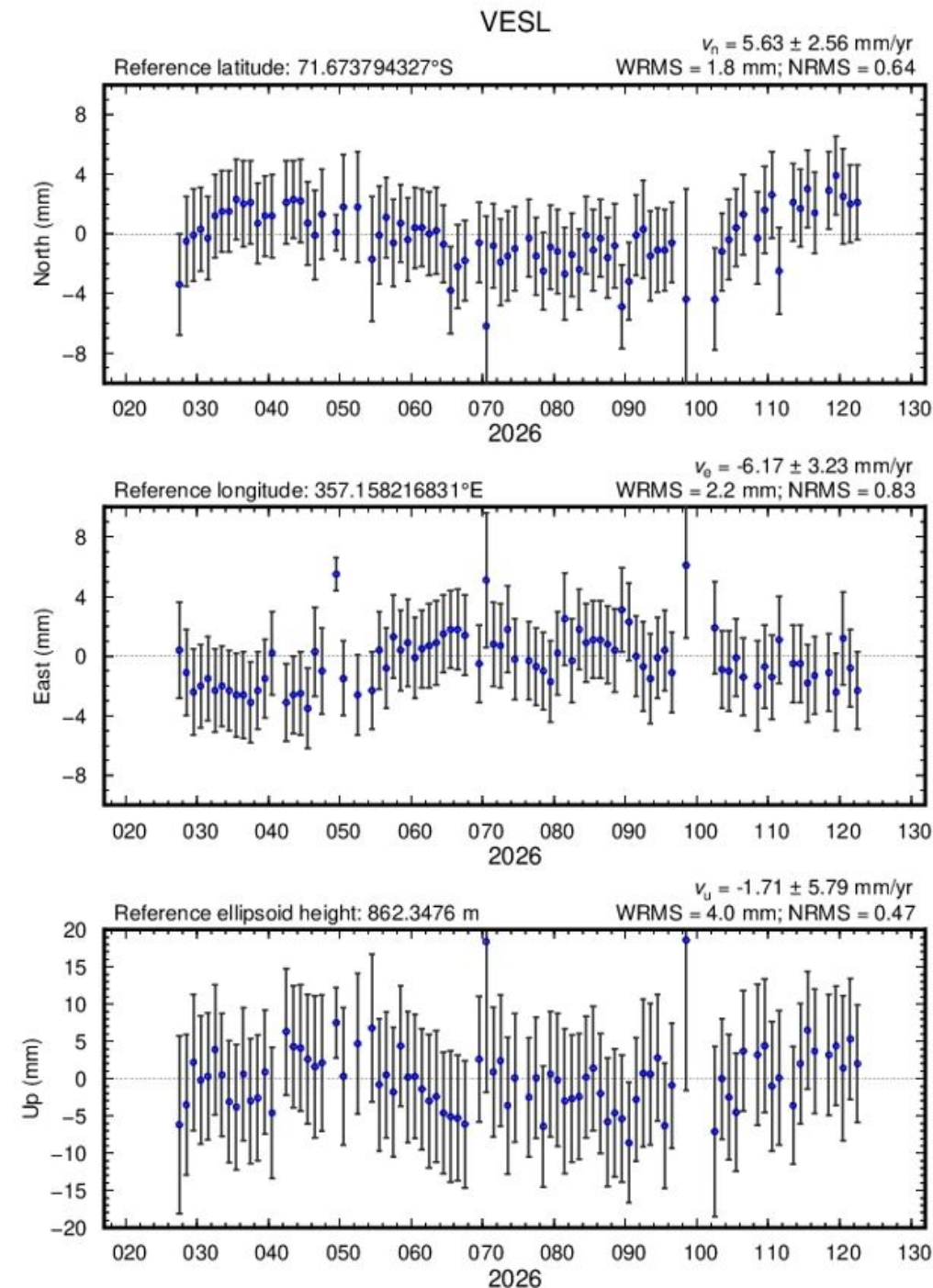
Sites are chosen based on:

- specific research interest in a local / regional phenomena
- supporting other sciences / measurements / instruments



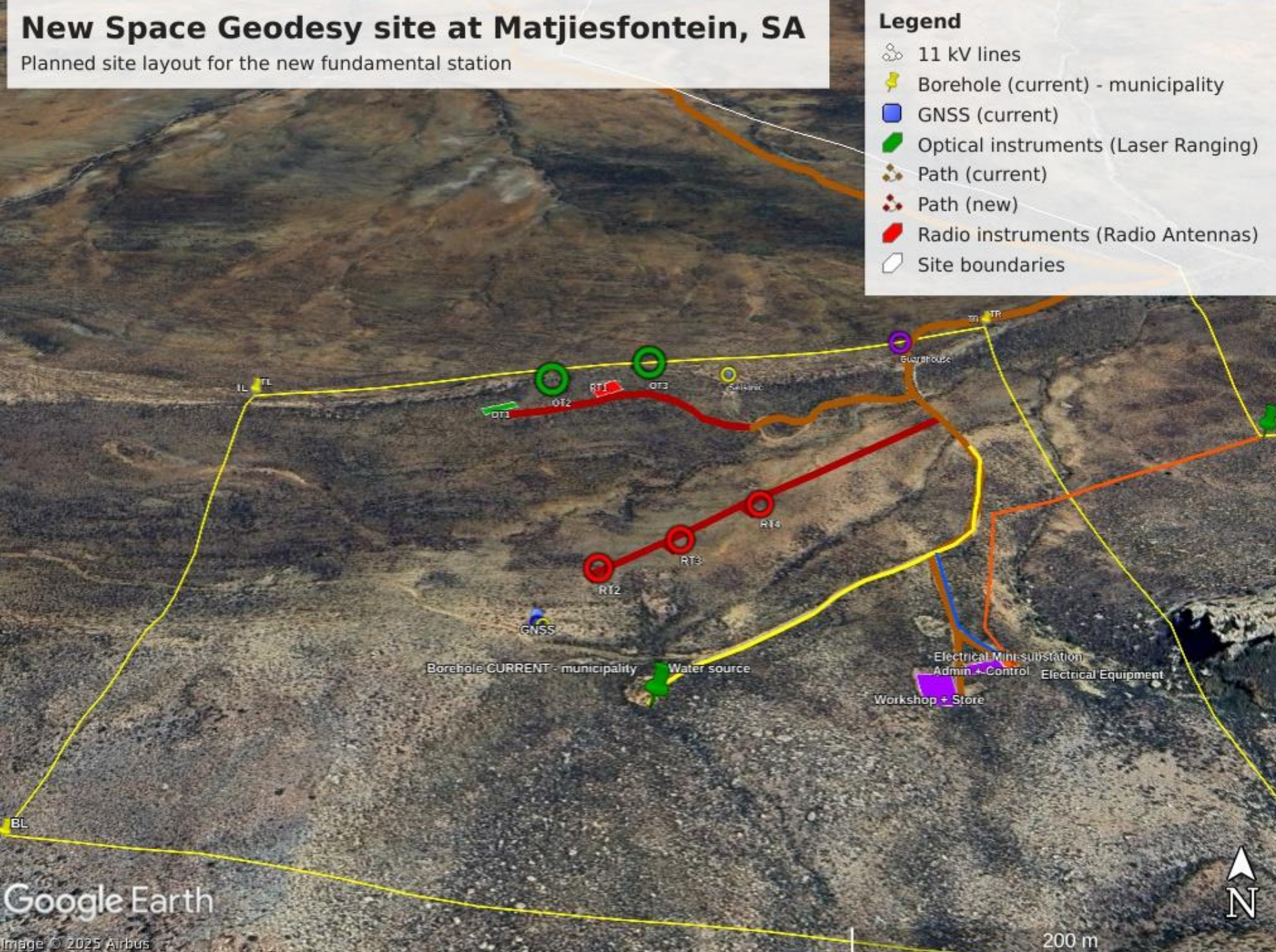
GNSS operations

- VESL station hardware installed and running since 28 January 2026. Ongoing comms issues with the base, IGS registration to follow once intrnet stable c
- Ongoing work on hosting agreements:
 - Chinese GNSS hosting agreement, signing stage for SLAs for 2 sites (Hart, Matjies)
 - Trignet station in the Karoo
 - Russian GNSS hosting
- Remote station network batteries upgrade to LiFEPO4
- Connectivity (remote sites): issues with some contracts



New Space Geodesy site at Matjiesfontein, SA

Planned site layout for the new fundamental station



First equipment established during 2007 (GNSS)

Current equipment:

- SARAO GNSS + Meteo
- Seismometer and accelerometer
- ESA GNSS
- AllSky Camera
- Seeing monitors
- Cloud sensor
- Chinese Academy of Sciences GNSS

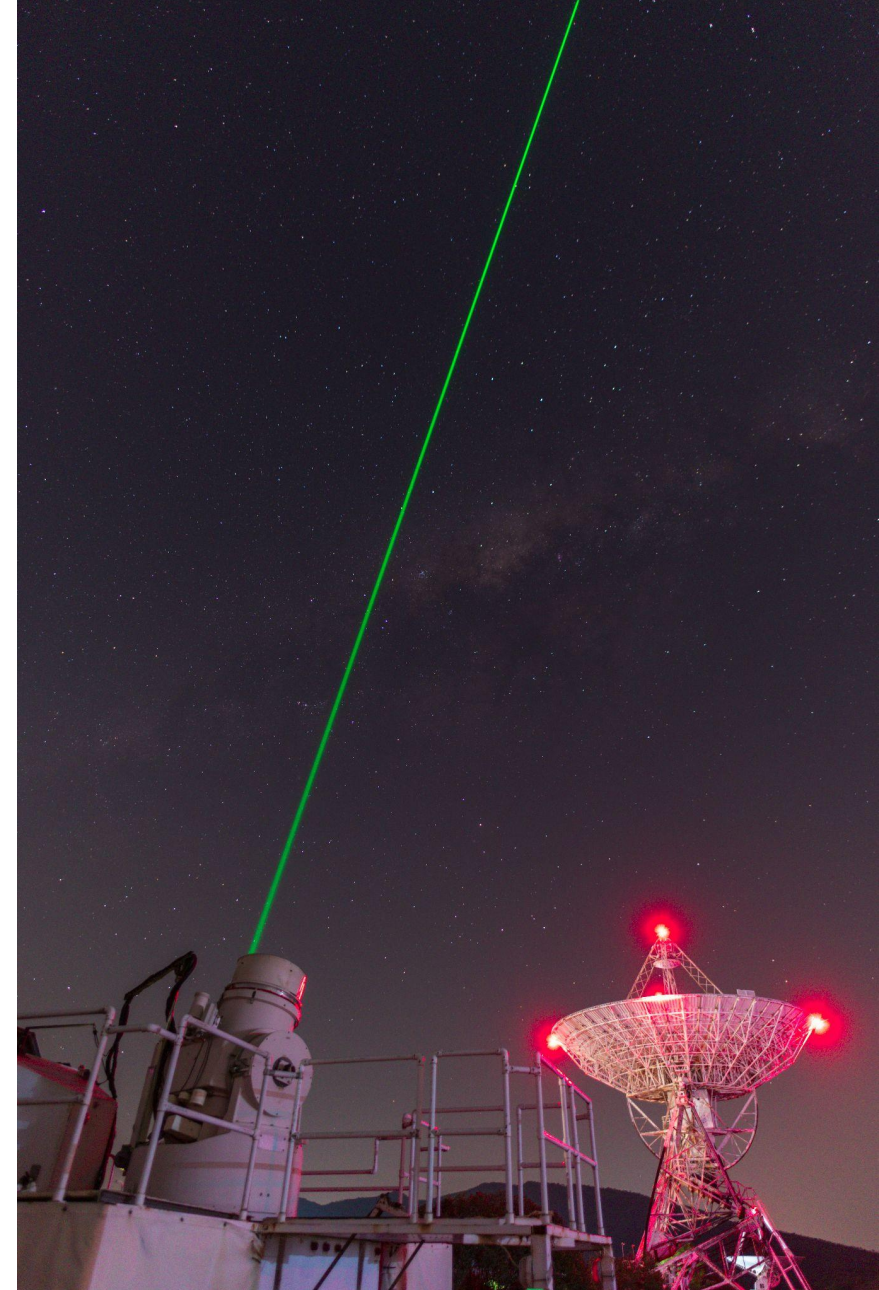
Obstacles and Challenges

- Bleeding staff and expertise for the last 2 decades
- Resistance to implementation of the recommendations made following the Geodesy Programme Review
- Funding stream from NRF, the Strategic Research Infrastructure Grant (SRIG), dried up
- Cumbersome processes to allow new hosting agreements to be established



Future plans

- Hartebeesthoek site:
 - **Reference transfer from 26m to VGOS: parallel observations with 26m will have the datum transferrable by 2035**
 - IF the 26m bearings fail before 2035, they will need to be replaced.
 - Operate the 15m
 - **Improve the local tie with increased automation and measurements**
 - **Geodetic VLBI Correlation capabilities**
- Matjiesfontein site:
 - **Infrastructure establishment (power, internet and road, security) - budget to be proposed**
 - Hosting of instruments to be expanded to SLR and RA instruments
 - Addition of DORIS @ SANSA's Matjiesfontein site
 - Parallel operation to Hartebeesthoek for 10+ years to obtain a new reference point / datum





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SAGWG
South African Geodesy
Working Group

Thank you



The SARAO Hartebeesthoek site
during April 2020.
Photo Credit: R Botha