SAGWG
South African Geodesy Working Group

Lightning update: South African Radio Astronomy Observatory

By: Roelf Botha
Manager: Space Geodesy

NRF National Research Foundation | SARAO South African Radio Astronomy Observatory

science, technology & innovation
Department: Science, Technology and Innovation
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land reform & rural development
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SAGWG - Workshop 1, 1 - 2 October 2025, SAAO, Cape Town

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

Origin & History

December 1960 — **Construction starts - NASA DSS51**

July 1961 — **Site is fully operational**

First scheduled mission was Ranger 1 (mission failed)
Initial receiver frequency: 960 MHz

8 September 1961 — **Official Opening**

1963 — **Main building was enlarged**

Slide credit: P Mey, SARAO

Origin & History

1964 — **26m antenna converted**

To Cassegrain system. New receiver operated at 2290 MHz

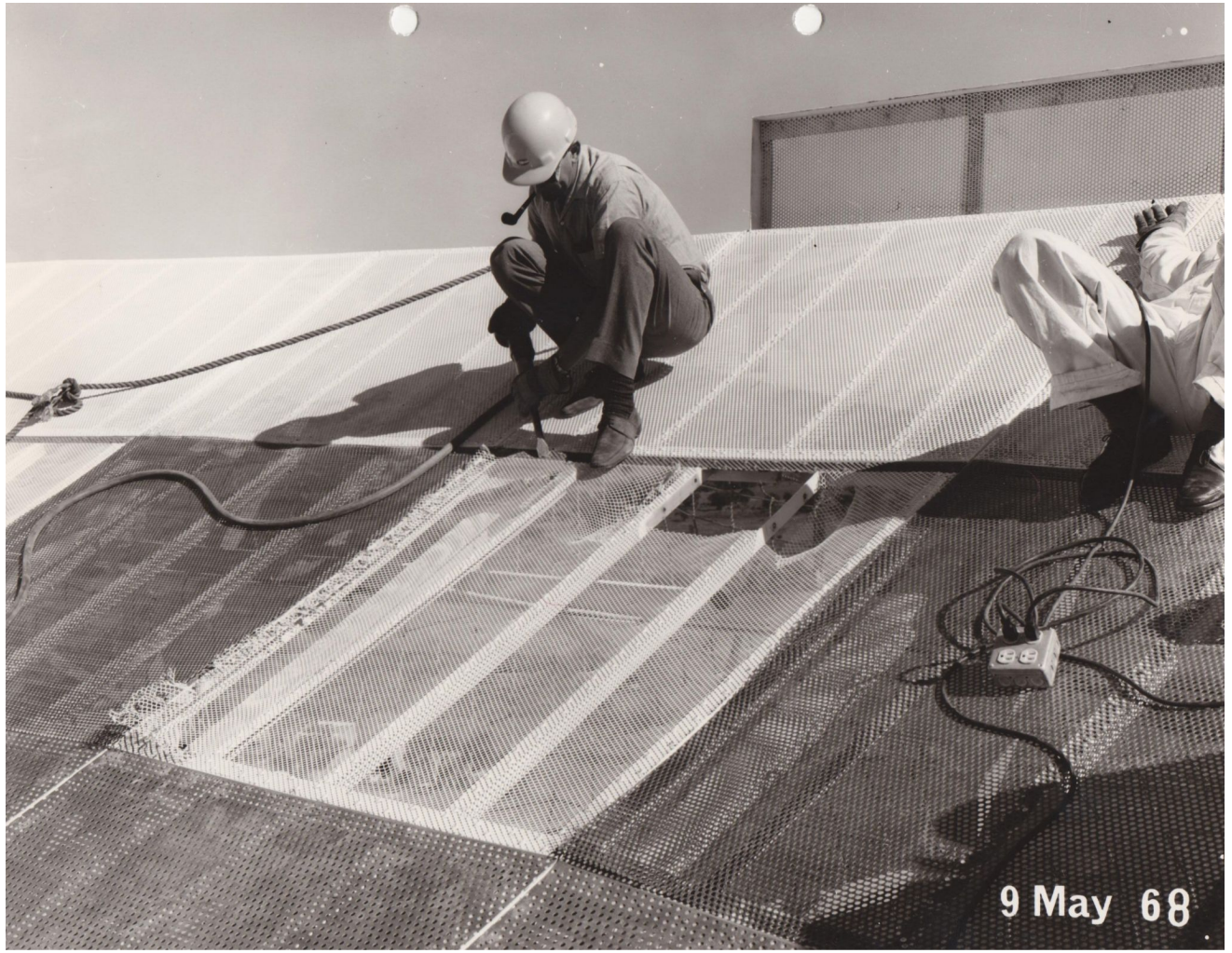
1968 — **Next phase of major structural upgrades**

1971 — **First inter continental VLBI**

Between South Africa (HartRAO) and Australia

July 1971 — **Apollo 15**

The only Apollo mission supported from DSS51 Hartebeesthoek



Slide credit: P Mey, SARAO

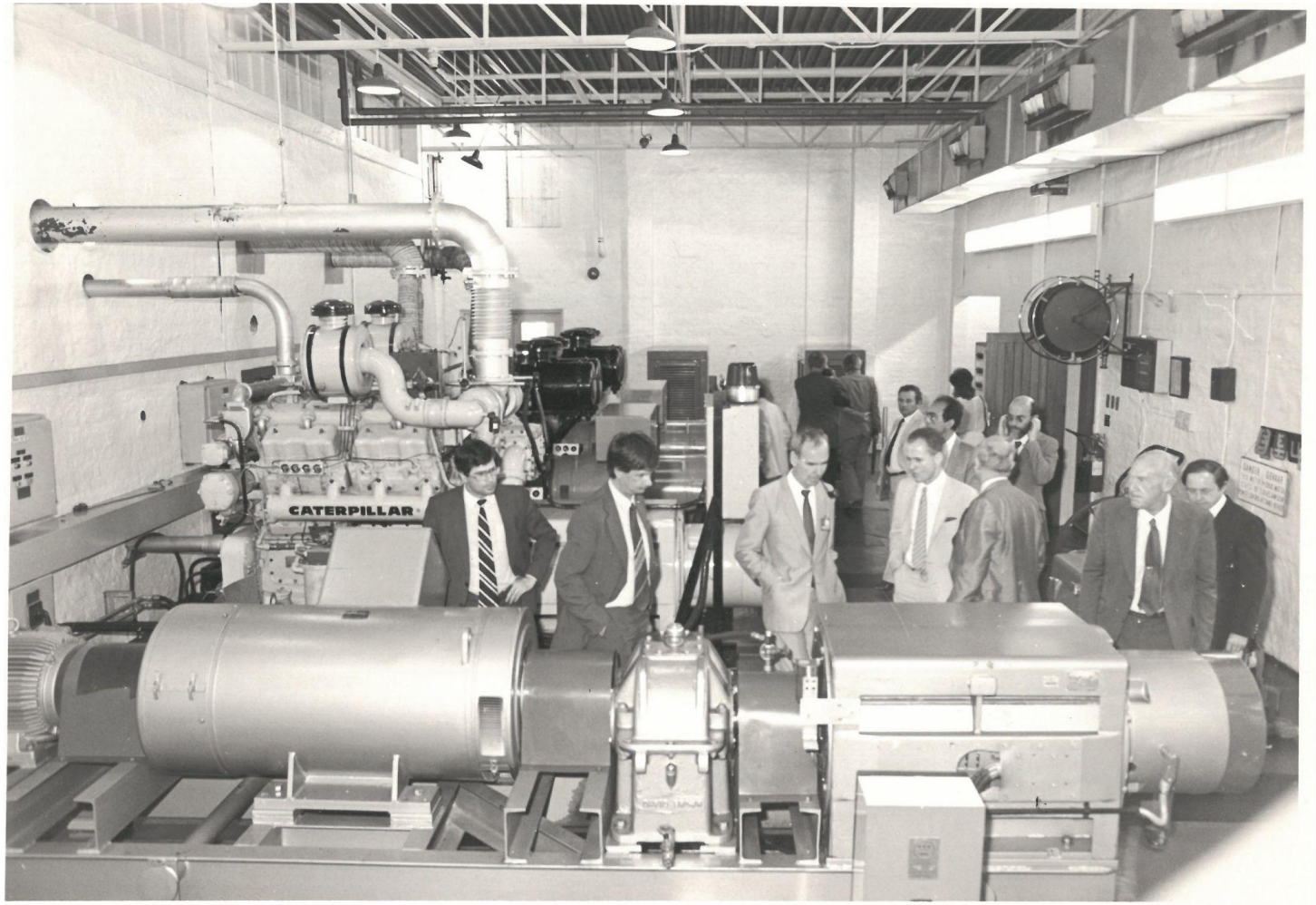
Origin & History

July 1973 — **NASA announced closing of DSS51 Hartebeesthoek**

1 March 1975 — **Hartebeesthoek Radio Astronomy Observatory**

1975 — **First time HartRAO was connected to the ESKOM grid**

1985 — **First Hydrogen MASER EFOS6 was installed**



Slide credit: P Mey, SARAO

Origin & History - Geodesy

1971 — **First intercontinental VLBI (NASA)**

1996 — **NASA GNSS station established (HRAO)**

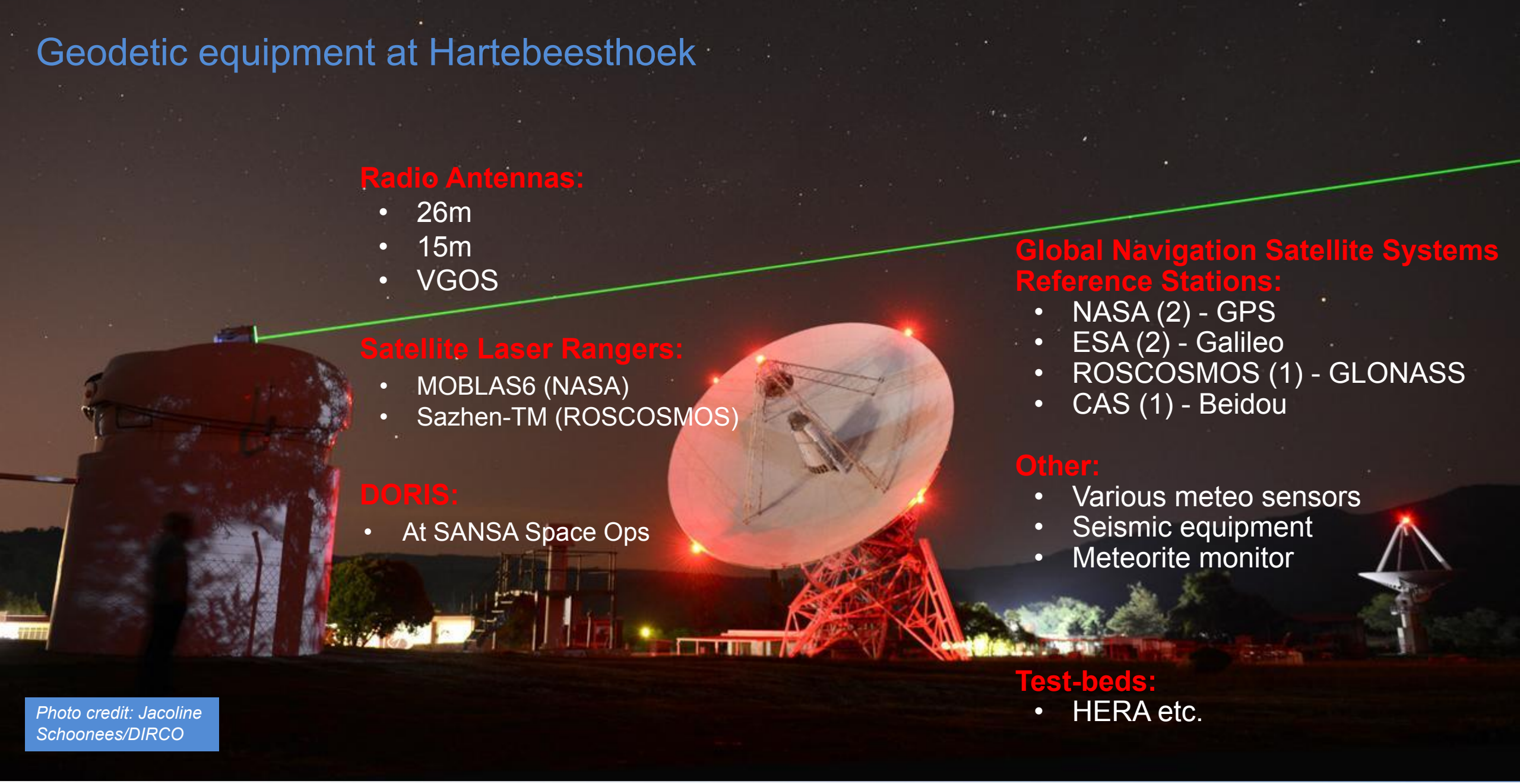
1999 — **NASA MOBLAS6 Laser Ranger operations commence**

2008 — **15m Geodetic VLBI operations commence**

2016 — **Sazhen-TM Satellite Laser Ranger operations commence**

2025 — **VGOS operations commence**

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

Other:
- Various meteo sensors
- Seismic equipment
- Meteorite monitor

Test-beds:
- HERA etc.

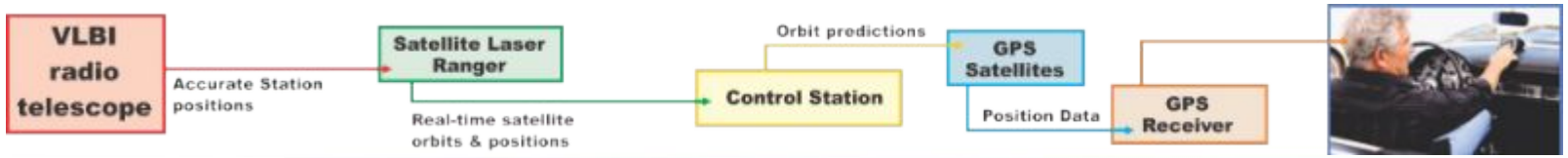
Photo credit: Jacoline Schoonees/DIRCO

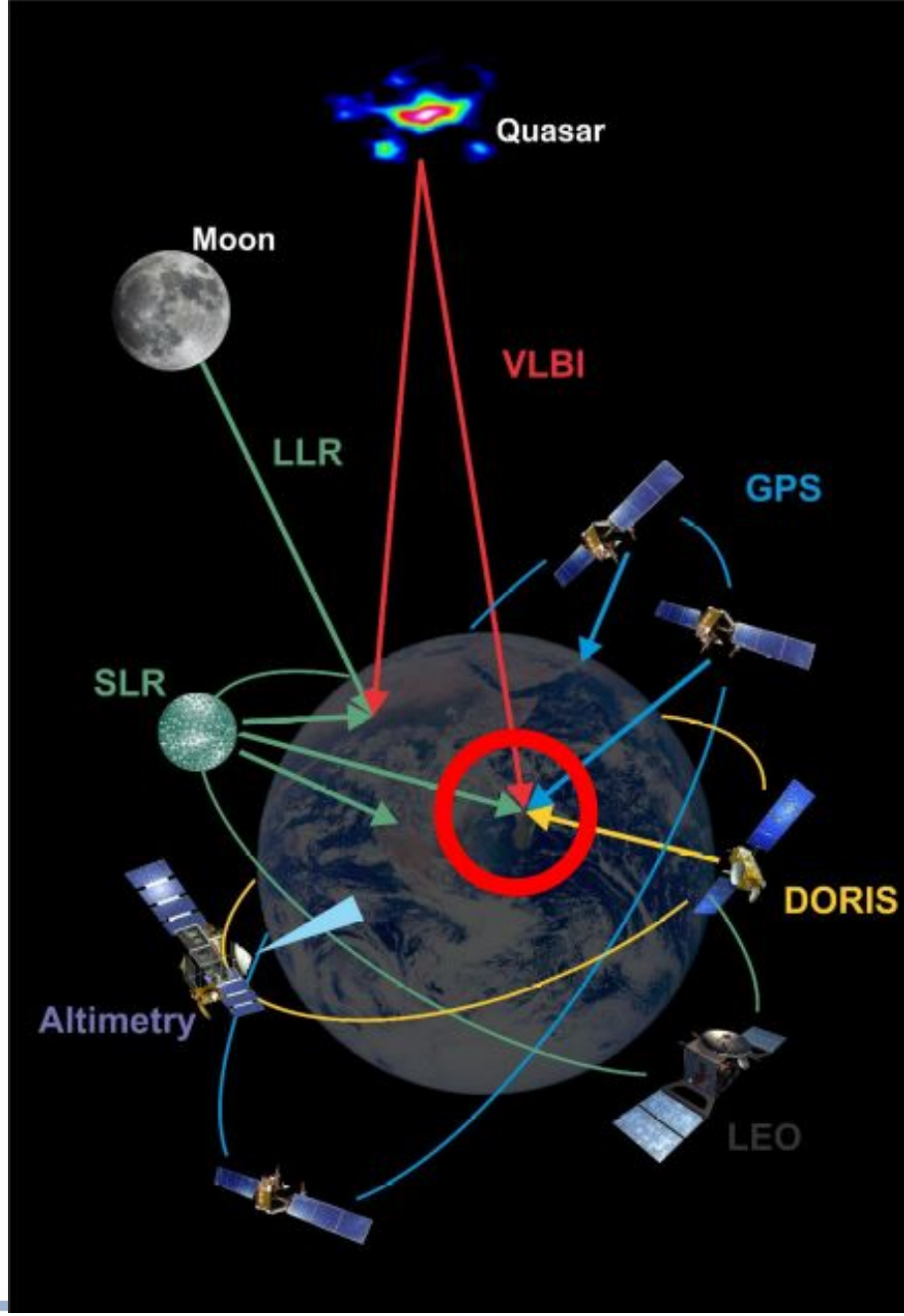
Geodetic equipment - Fundamental Site

- **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? C O L L O C A T I O N



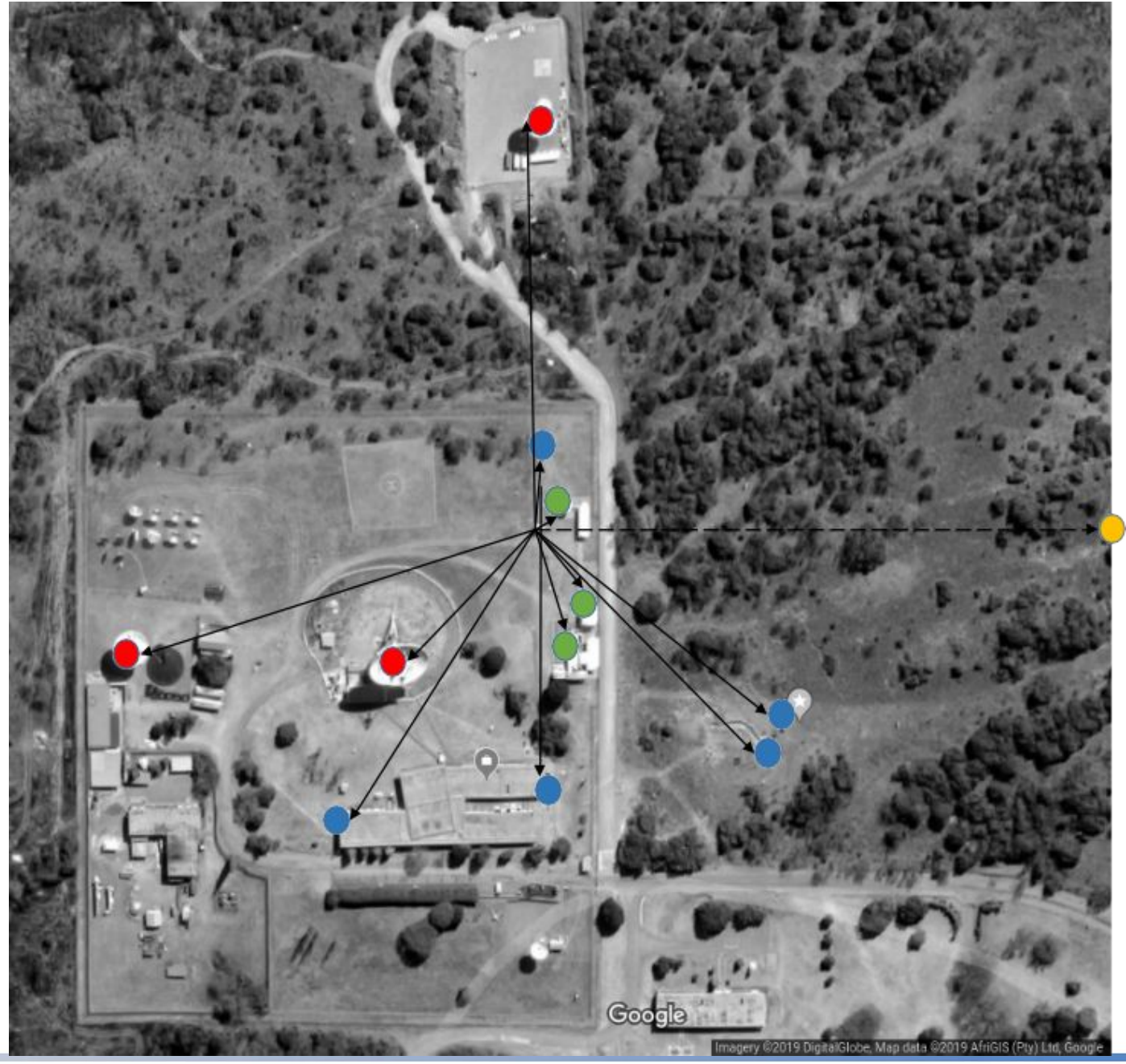


Fundamental Site - Site Tie

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

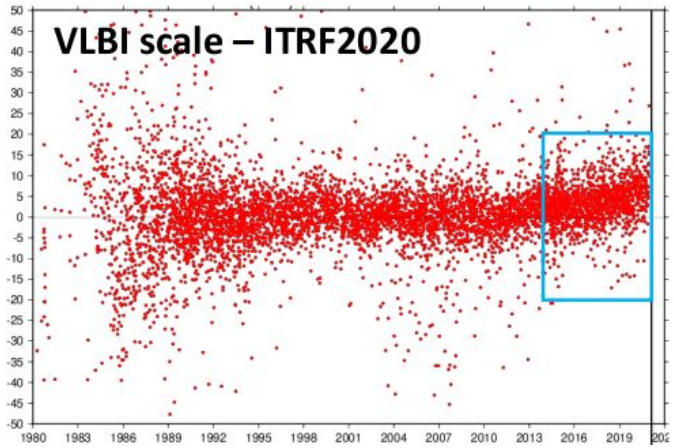


Geodetic equipment - Fundamental Site
Why collocation is important

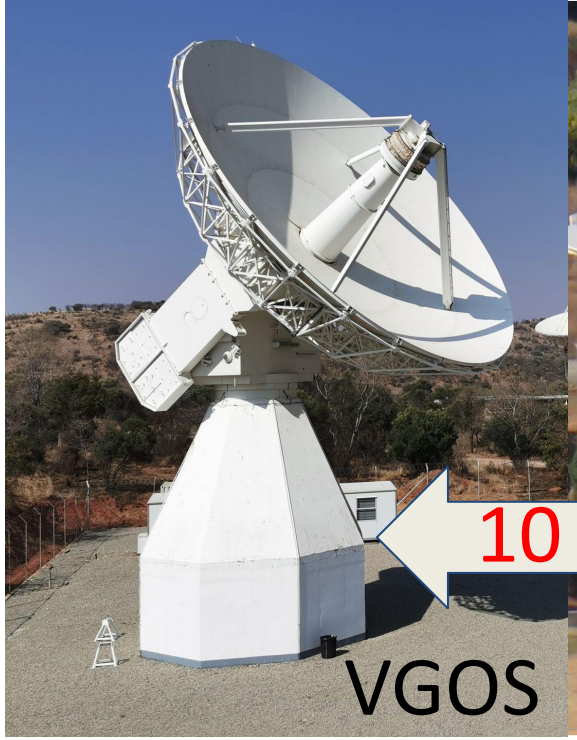
Parameter type	VLBI	GPS/ GLON.	DORIS/ PRARE	SLR	LLR	Alti- metry
Quasar Coord. (ICRF)	X					
Nutation	X	(X)			X	
Pole Coord. X, Y	X	X	X	X	X	
UT1	X					
Length of day (LOD)		X	X	X	X	
Sub-daily ERPs	X	X				
ERP Amplitudes of ocean tides	X	X		X		X
Station Coord.+ Velocities (ITRF)	X	X	X	X	X	(X)
Geocenter		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			

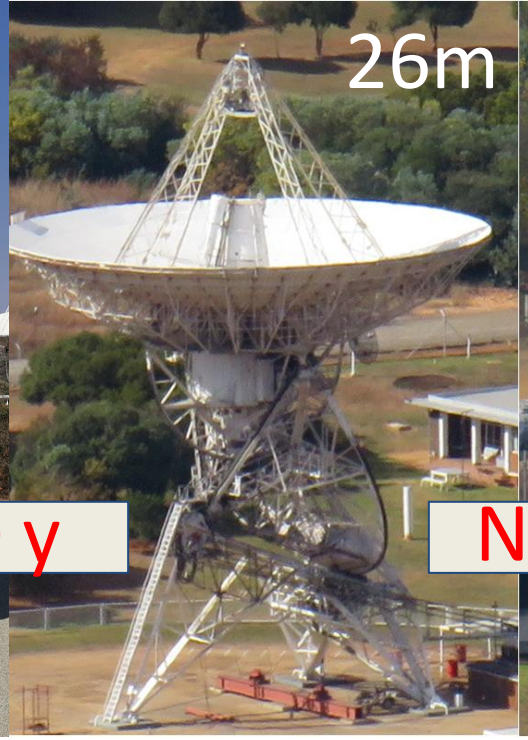
Hartebeesthoek94 Datum

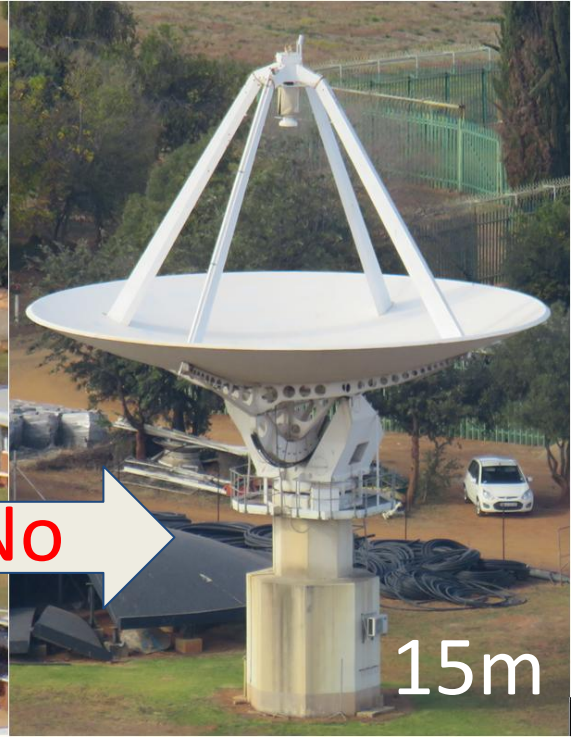
1. Hart94 Datum (26m)
2. Scale problem: Determined that 15m has stability issues - the result rendering it not viable as reference



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







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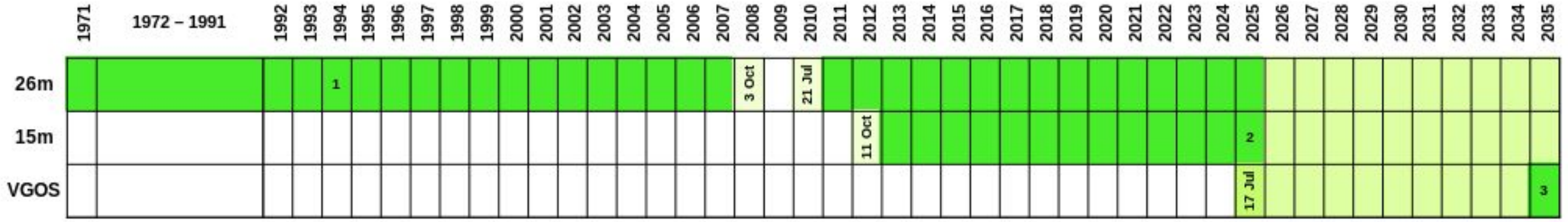
No

3. To transfer the reference from 26m to VGOS, 10 years of parallel observation between 26m and VGOS required.

HART15M:
➢ ITRF2020 update data gap - 2016, doy 288;
➢ Non linearity - 2021, doy 001.



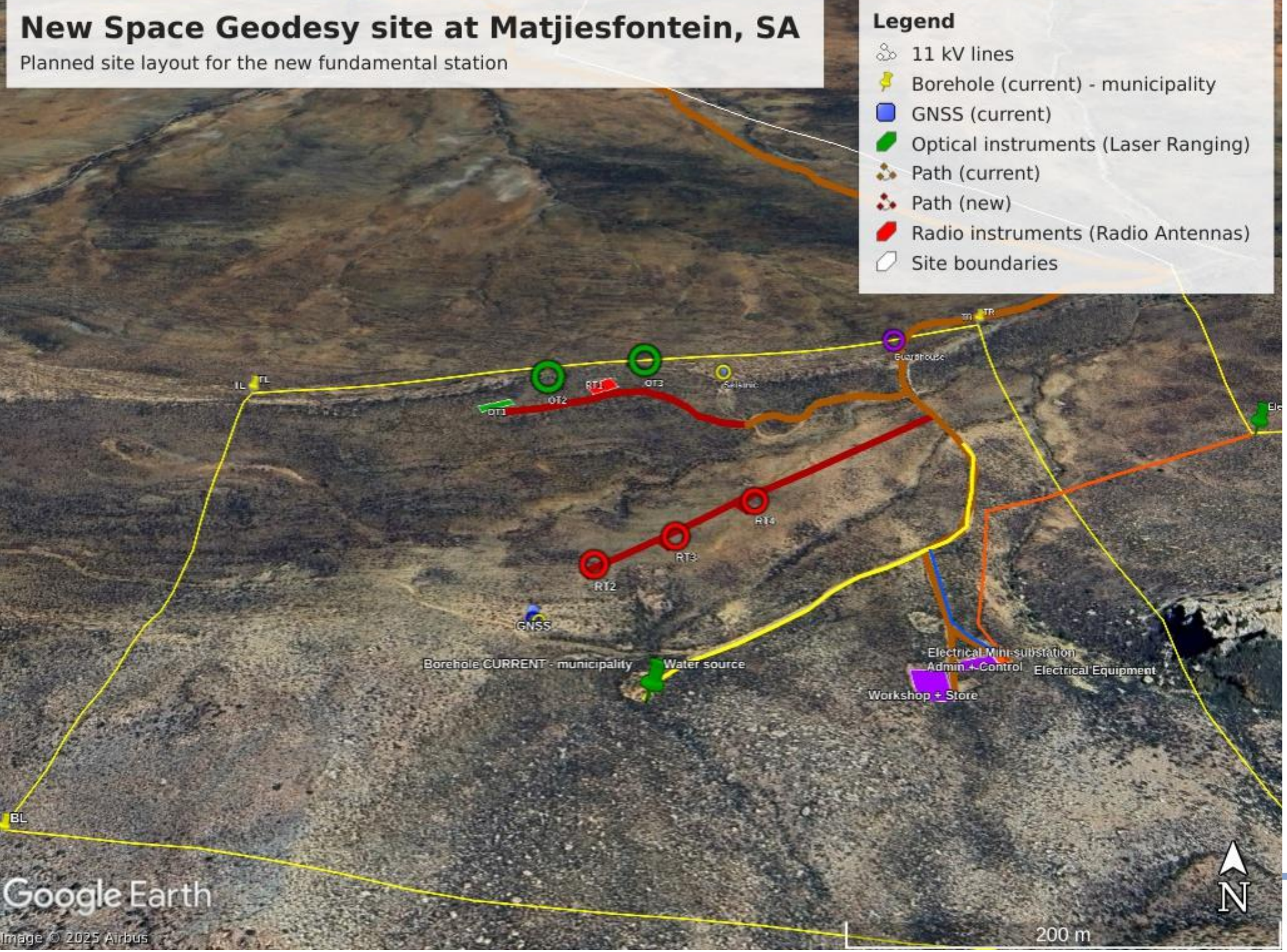
Geodetic equipment - remote stations

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



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

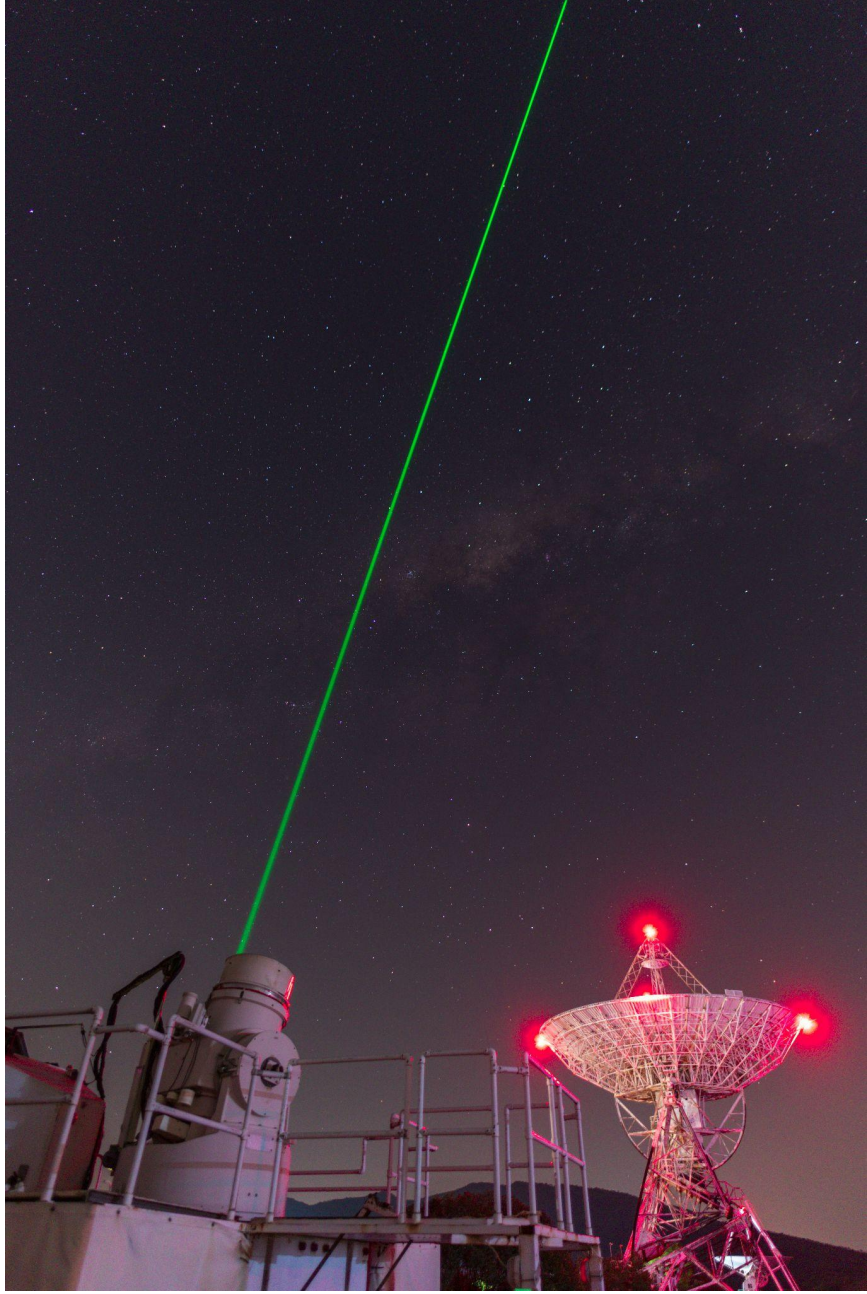
Obstacles and Challenges

- Bleeding staff and expertise for the last 15 years
- Resistance to implementation of the recommendations made following the Geodesy Programme Review
- Funding stream from NRF, the Strategic Research Infrastructure Grant (SRIG), dried up
- Motivations and recommendations path required for even the most basic of hosting / other activities of a space geodetic observatory
- Cumbersome processes to allow new hosting agreements to be established

Future plans

- Hartebeesthoek site:
  - Repair of the 26m bearings to enable another 20+ years of operations
  - Operate the 15m
  - VGOS observations for 10 years in parallel with 26m will have the datum transferred by 2035
  - Improve the local tie with increased automation and measurements

- Matjiesfontein site:
  - Infrastructure establishment (power, internet and road, security)
  - 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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Thank you

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