Yebes Observatory: Future Core Site and Laser Ranging Station Status

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1. Abstract

Yebes Observatory, located in the center of Spain (80km from Madrid), will become in the next years the first Core Site in the Iberian Peninsula. Currently, there are two space geodesy techniques present in the Observatory (VGOS and GNSS) in addition to the Gravimetry laboratory (absolute gravimeters and superconducting relative gravimeter). The project for building a Laser Ranging Station at Yebes Observatory has just begun. The station applications (SLR and Space Debris tracking) and main specifications, following the GGOS Project requirements, are already established.
First contacts with companies and institutions have been carried out and the funds are available, allowing Yebes Laser Ranging Station (YLARA) to be in operation in the next four years and ready to be included into the ILRS network.

2. Yebes Observatory introduction

Yebes Observatory, founded in the late 70s, is located in the center of Spain (80km from Madrid), a strategic place in the limit of the European Tectonic Plate. Thanks to the RAEGE Project (Atlantic Network of Geodynamical and Space Stations) and the European Regional Development Fund (ERDF) the Observatory will become in the next years the first Core Site in the Iberian Peninsula. Currently, there are two space geodesy techniques present in the Observatory (VLBI) and GNSS) in addition to the Gravimetry laboratory (absolute gravimeters and superconducting relative gravimeter), the local tie network, time and frequency system and other facilities.
To fulfill a Fundamental Geodetic Station, following the requirements of the GGOS Project, just a Laser Ranging System is necessary to be added. The project for building a Laser Ranging Station at Yebes Observatory has just begun. The station applications (Satellite Laser Ranging and Space Debris tracking) and main specifications are already established. First contacts with the sector companies and institutions have been carried out and the funds are available for building the complete system, allowing Yebes Laser Ranging Station (YLARA) to be in operation by the end of 2020. Fulfilling the demanded ILRS requirements would allow the station to be included into the ILRS network.

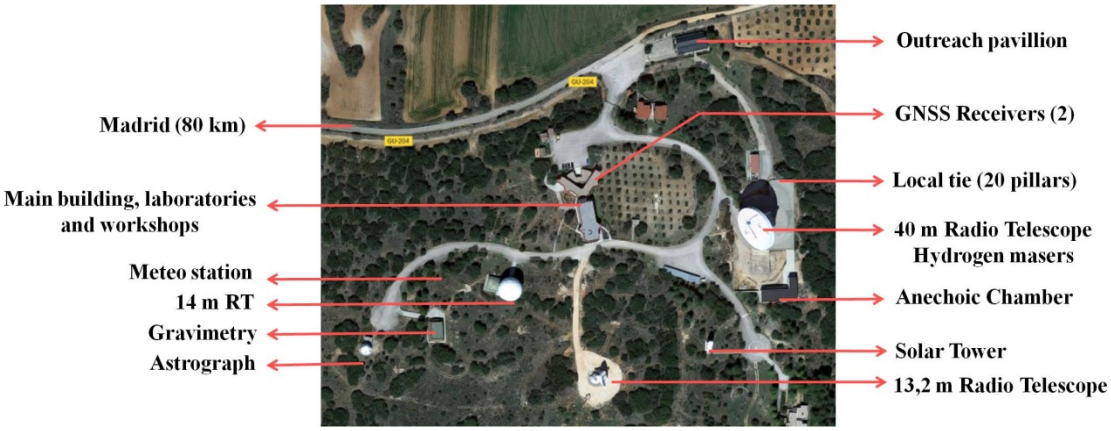

Figure 1: Yebes Observatory layout


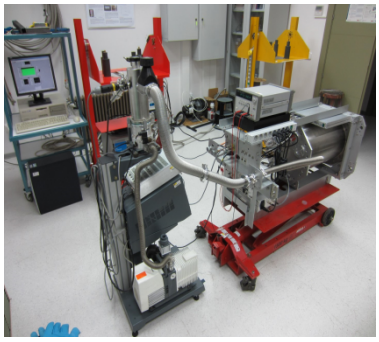
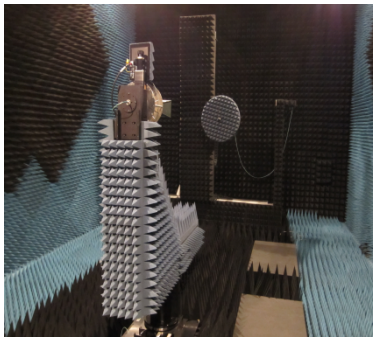
Figure 2: 40m RT. Geodesy and astronomy applications. From 2 to 100 GHz
Figure 3: State of art laboratories: cryogenic receivers, low noise amplifiers, up/down converters, mechanical workshops...
Figure 4: Anechoic Chamber (planar and spherical near field systems for antenna measurements)

3. The RAEGE project

Establishment of an Spanish-Portuguese Network of Geodynamical and Space Stations (RAEGE) by the installation and operation of four fundamental geodetic stations provided with radio telescopes with VGOS specifications in Yebes (1), Canary Islands (1) and Azores Islands (2).

Figure 5: RAEGE network

Initial equipment to be installed at each RAEGE station:

- Geodetic VGOS radio telescope: 13.2 m diameter, frequency ≥ 40 GHz
- Gravimeter (absolute, relative superconducting)
- Permanent GNSS station
- Satellite Laser Ranging (at Yebes Observatory)

Radio Telescope characteristics

- Maximum AZ/EL velocity 12°/sec and 6°/sec (acceleration 3°/sec²)
- Upper operational frequency 40 GHz (200 microns rms surface accuracy).
- Possible upgraded to 100 GHz. Path length error < 0.26 mm.
- Physical range in elevation 0 - 100°, azimuth 540° (+ 270 degrees)
- Overall pointing precision < 16 arcsec
- Power consumption <170kW

Figure 6: Yebes Observatory VGOS radio telescope

4. Yebes as a Core Site (status and available techniques)

4.1 VGOS radio telescope (13.2m diameter)

Yebes Observatory Developments for VGOS

- **Triband Receiver**
  - S band: 2.2-2.6 GHz, X band: 7.5-9.0 GHz, Ka band: 28-33 GHz
  - Installed in February 2014 for radio telescope commissioning
  - Other Triband systems: Japan and Santa María in Azores
  - Future installation at Ny-Älesund Observatory (NMA)
- **Broadband Receiver (from 2 to 14 GHz)**
  - Dual lineal polarization, noise temperature under 25 K
  - Using a quadruple-ridged flared horn (QRFH) from Caltech
  - Installed in February 2016 for VGOS Broadband observations
- Low Noise Amplifiers: S, X and Ka bands and broadband for VGOS
- Frequency up/down converters
- Phase and gain calibration modules

First Transatlantic VGOS Fringes (june 2016): Yebes antenna was one of the radio telescopes involved in the observations with Kokee Park (Hawaii), GGAO (Maryland), Westford (Massachusetts), Wettzell (Germany) using broadband systems.

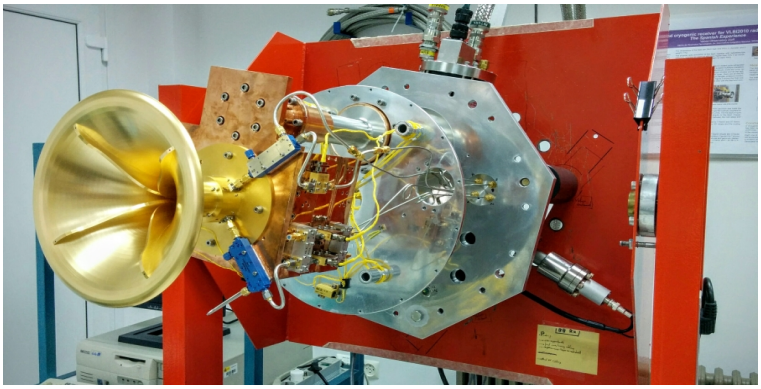

Figure 7: Yebes VGOS broadband receiver

4.2 Gravimetry pavillion

- Seven pillars for instrument installation and intercomparisons
- Two absolute gravimeters (A10 & FG5)
- OSG Superconducting gravimeter (Feb - 2012)
- Participation in IGETS - International Geodynamics and Earth tide Service

Figure 8: Gravimetry pavillion

4.3 GNSS receivers

There are two GNSS receivers installed at Yebes Observatory.

Figure 9: GNSS receivers

4.4 Local tie

Studies to define the best network configuration allow us to get the local tie with an accuracy below 1 mm. The complete network is composed by 24 vertex including on it the radio telescopes and the GNSS antennas

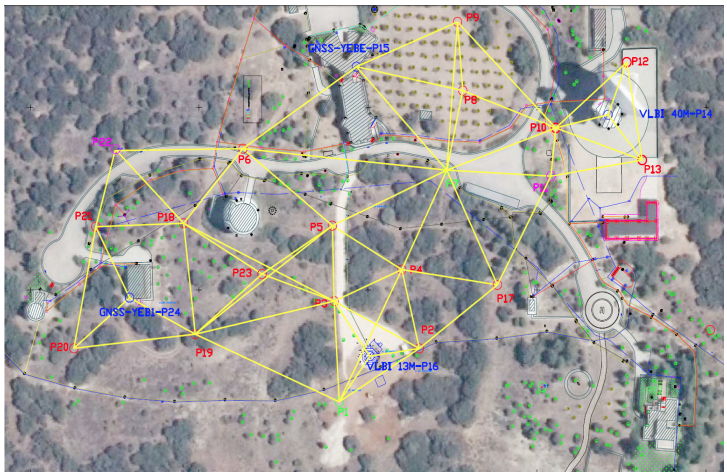

Figure 10: Yebes Observatory local tie

Pillars are made of concrete and iron and compose by a 30 cm diameter cylinder inside a protector tube.

Figure 11: Local tie pillar

5. Future Yebes Laser Ranging (YLARA) station

Yebes Observatory is one of the Singular Scientific and Technological Infrastructures (ICTS) in Spain, the only one in the Castilla-La Mancha Region. The ICTS are facilities, resources, equipment and services, unique in its kind, and dedicated to cutting edge high quality research and development, to promote transfer, exchange and preservation of knowledge, technology and innovation.

⇒ ERDF 2014-2020 Funds - Ministry of Economy and Competitiveness of Spain (FICTS1420-11-12)

The Economic and Technical ERDF Memory establishes the next preliminary work schedule for the construction of the YLARA system.

Work Schedule	2016				2017				2018				2019				2020			
SLR building and infrastructure				X	X	X	X	X	X	X										
Telescope and dome subsystems					X	X	X	X	X	X	X	X	X	X	X	X				
Optic Subsystem							X	X	X	X	X	X	X	X	X	X	X	X		
Measurement subsystem							X	X	X	X	X	X	X	X						
Software Package and security system							X	X	X	X	X	X	X	X	X	X				
System Engineering and Integration											X	X	X	X	X	X	X	X	X	X
Project Management and Quality Assurance			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Promotion			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Figure 12: Project schedule

Yebes SLR station preliminary design specifications:

Observations to satellites equipped with retro-reflector

- Satellites observations from 400 - 42000 km
- Pulsed Solid State Laser
  - Repetition rate ≥ 1000 Hz
  - Pulsed width < 25 ps
  - Wavelength: 532 nm (Nd:YAG – Nd:Van)
  - Energy: 0.5 - 2 mJ
- Biaxial telescope, AZ-EL mount
  - Receiving system: 50-60 cm
  - Transmitting system: 10 cm
  - Pointing accuracy: 5-7''
  - High slew rate
- Detector: CSPAD, (QE 20%)
- Range Gate Width: 100-400 ns
- Frequency Standard: Hydrogen maser
- Event timer
- Highly automation system
- Aircraft safety system compatible with other geodetic systems in the observatory

Space debris observation capacity

- To be determined:
  - Monostatic/bistatic observation
  - Laser system characteristics (power, color, repetition rate, etc.)
  - Specific software