# MAGAL Constellation


1. Arlindo Marques
2. Clara Lázaro, M. Joana Fernandes
3. Joaquim Melo
4. André G. C. Guerra, André João, Miguel Martin, Miguel Arantes, Paulo Figueiredo
5. Vitor Coelho, Nuno Borges Carvalho
6. Catarina M. Cecílio
7. Ana Martins
8. Yaroslav Mashtakov
9. Edgar Carrolo
10. Burke Fort, Byron Tapley, Brian Jones
11. Hugo Silva

1. efacec 2. ciimar 3. AIR CENTRE 4. CEIIA 5. instituto de telecomunicações 6. CoLAB +ATLANTIC 7. Gaspar Frutuoso Fundação 8. Universidade Beira Interior 9. omnidea 10. TEXAS The University of Texas at Austin 11. Técnico Lisboa


## A New Space Approach

MAGAL project aims to define a new satellite constellation, based on small satellites, e.g. CubeSats, for ocean monitoring at local, regional and global scales, carrying a new innovative radar altimeter. MAGAL is aligned with the European "New Space" agenda, aiding Portugal towards becoming a space nation.

MAGAL constellation main goal is to improve the current temporal sampling of the ocean from 10 to 5 days, keeping, at the same time, the spatial sampling and data accuracy. Its main payload is a custom state-of-the-art radar altimeter (capable to fit in an 1.5U CubeSat).

MAGAL is also developing a new concept of Data Centre to work as a Full Integrated Service, not restricted to MAGAL data only, but combining them with other data sources, to provide a complete set of services and products with higher added value to end-users, in specific layers, which can be accessed depending on the user permissions.

MAGAL involves major Portuguese industry and science players, aiming the leverage of space industry at all supply chain phases, from conceptual design to launch and data usability.

## 1. Objectives

**| Scientific**
- Ocean-climate change studies
- Academic advancement

**| Engineering**
- Constellation Design
- Concurrent Engineering

**| Technological**
- Platform Design
- Payload Development

**| Entrepreneurial/Business**
- Big Data Analytics
- Visualization

## Proof of Concept

**Can an innovative technological concept such as a constellation of small satellites with radar altimeters, not yet implemented to date, contribute to the future of Satellite Altimetry?**


Improve on-orbit capability at reduced system cost

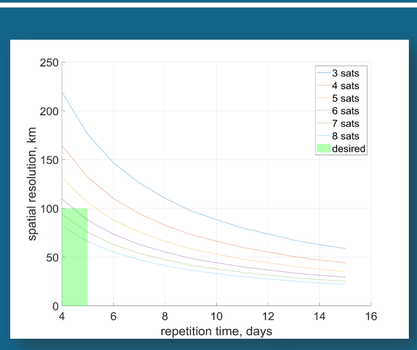
## 2. Uses Cases

**| Sea Surface Topography**
**| Eddy Detection and Tracking**
**| Marine Debris Monitoring**
**| Inland Water Levels**

**Use cases require to:**
- **Sample the global ocean in 5 days**
- **Maintain the current spatial sampling and combine MAGAL and the large satellite altimetry missions to improve spatial sampling**

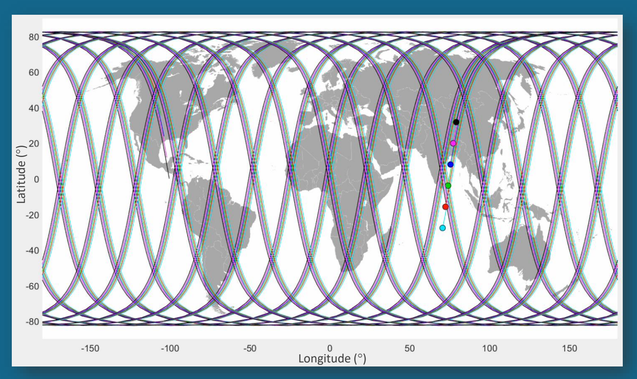
## 3. Constellation

- **Orbit type:** SSO
- **Altitude:** 499.85 km
- **Inclination:** ~97.4°
- **N.º of satellites:** 6 (single orbital plane)
- **Orbit Repetition**: within ±1 km
- **Nadir Pointing**: better than 1° (±0.01°)
- **Repetition cycle:** 5 days
- **Revolutions per repetition cycle:** 76
- **Spatial sampling at the Equator:** ~88 km



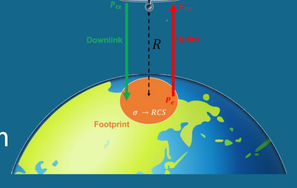

◄ Fig. 1 - Distance between adjacent ground-tracks (spatial sampling at the Equator) versus repetition cycle, considering a constellation of 3 to 8 satellites (green shaded area represents the desired scales).

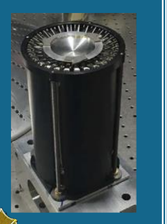
► Fig. 2 - MAGAL ground tracks for one day considering a constellation of 6 satellites in the same orbital plane.

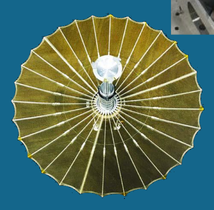



## 4. Radar Altimeter [1]

- **Developed by:** EFACEC and IT Aveiro, miniaturized
- **Technology**: Frequency Modulated Continuous Wave (FMCW)
- **Operating frequency**: Ku-band - 13.0 – 13.2 GHz
- **Distance accuracy:** better than 30 cm (single measurement, no corrections)
- **Accuracy of a single measurement after dedicated processing:** 2-3 cm
- **Distance measurement rate:** 20 Hz
- **Footprint Area:** around 5 km²
- **Range profile** @ 1 Hz rate
- **Budgets**:
  - **Power**: < 20 W
  - **Envelope**: 15 cm × 10 cm × 10 cm
  - **Mass**: < 3 kg
  - **Maximum transmitted power**: about 1 W (30 dBm)
- **Antenna:**
  - Deployable dish antenna, 1.5 m diameter
  - **Weight**: < 12.5 Kg
  - **Envelope**: 50 cm × 30 cm × 10 cm
- **Science**:
  - **Received Signal Strength Indicator (RSSI):** to derive the radar cross-section of the measured surface
  - **Range profile:** FFT of the measured distance over a minimum delta range of 100 m, to increase the distance accuracy/data reliability

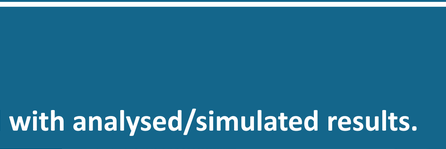


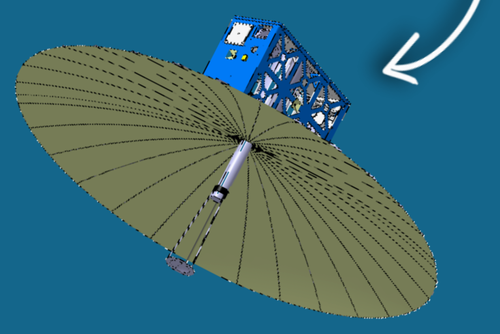





## 5. Satellite & Payload

- **Satellite shape (CubeSat):** 24U
- **Satellite weight:** 70 kg
- **Cost:** 3 M€
- **Launch cost:** 6 M€
- **Timeline procurement, manufacturing and testing:** 2 to 3 years
- Based on COTS system (except the Radar Altimeter)
- 3 years lifetime





▲ Fig. 3 - MAGAL Satellite with RA antenna.

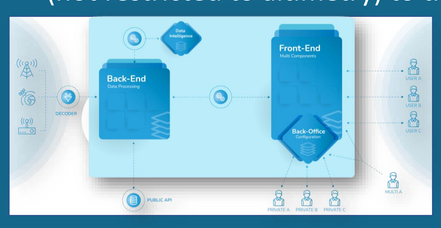
- **CPU & Memory**
- **Propulsion system**
- **Electrical power system with deployable solar panels**
- **Attitude & Control:**
  - **GNSS**
  - **Gyroscope**
  - **Magnetometer & Magnetorquer**
  - **3D reaction wheels**
  - **Sun tracker & Sun sensor**
  - **Star tracker**
- **Radar altimeter**
- **Laser reflector array**
- **S-Band Communications**

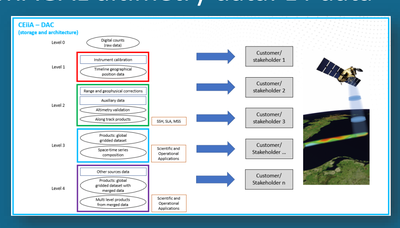
**| Integration of the equipment: started**

**| Consolidation of the equipment against interfaces and their integration into the satellite, together with overall budgets consolidation: ongoing**

## 6. Ground Segment

- **Ground Link:**
  - Minimum of 2 ground stations
  - Subcontracted through medium-long term partnership
  - Scope: download and upload of data and commands
- **Control Centre:**
  - Splits data packets, science and housekeeping
  - Decodes and serialise data: L0 data
  - Manages and control the satellite operations
- **Data Analysis Centre (DAC):**
  - Applies equipment corrections: L1 data
  - Applies range and geophysical corrections: L2 data
  - Applies altimetry algorithms to provide the defined services/products to end-users: L3 data
  - Provides additional layers, supporting added value services and products to end-users by the addition of others synchronized data (not restricted to altimetry) to the MAGAL altimetry data: L4 data

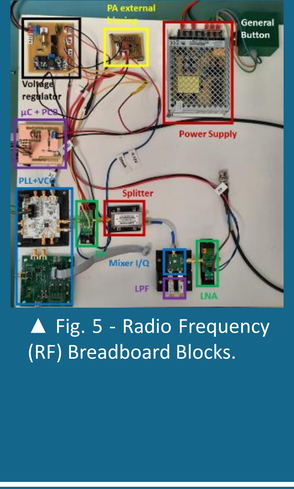


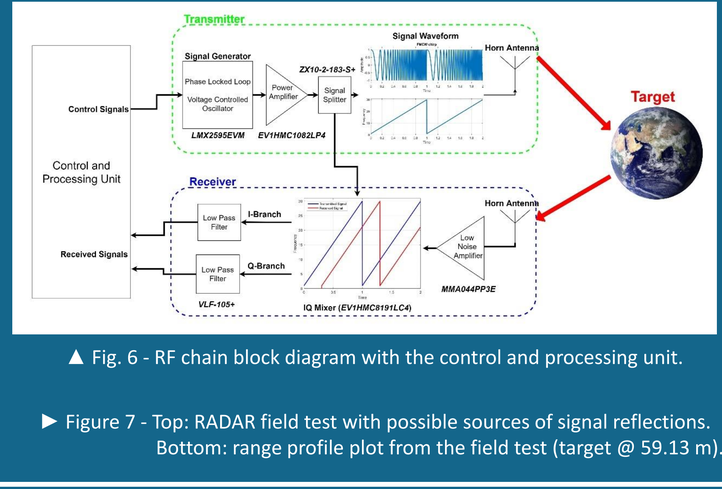

▲ Fig. 4 - The DAC is a repository for large volumes and a platform to disseminate service directly to end-users. Left: web development with back-end, ETL (Extract, Transform and Load the data) process and a front-end dashboard; modular approach with data processing parallelization. Right: different levels of Satellite Altimetry generated by MAGAL.

## 7. First Results [2,3]

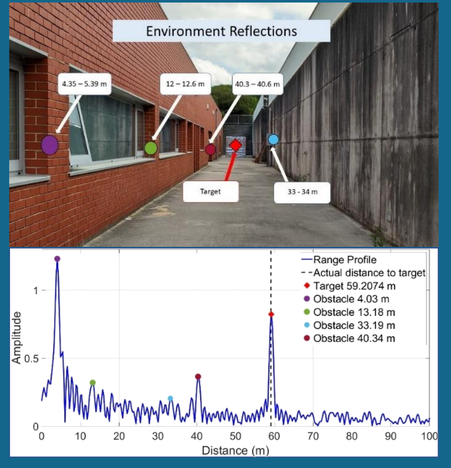
- **Radar Altimeter successfully tested; preliminary results fully aligned with analysed/simulated results.**




▲ Fig. 5 - Radio Frequency (RF) Breadboard Blocks.




▲ Fig. 6 - RF chain block diagram with the control and processing unit.




► Figure 7 - Top: RADAR field test with possible sources of signal reflections. Bottom: range profile plot from the field test (target @ 59.13 m).

## 8. Conclusions

MAGAL aims to be a proof of concept of an innovative technological concept such as a constellation of small satellites carrying RA, not yet implemented to date, to improve on-orbit capability at reduced system cost for ocean monitoring and climate studies and to redefine the future of Satellite Altimetry.

MAGAL project is being developed as a strong partnership between Portuguese industry and scientific community, together with UT Austin. For more details: https://projects.efacec.com/magal/.

## References:


1. ARSI+KEO 2022 - "Simulation of an FMCW RADAR Altimeter for a Cubesat"
2. SHaRC 2023 - "Characterization of a RADAR Altimeter Prototype System for CubeSat Applications"
3. SHaRC 2023 - "Design and Prototype of a RADAR Altimeter System for CubeSat Applications"



**Acknowledgments:**
This research was supported by the strategic funding UIDB/04423/2020 and UIDP/04423/2020 through national funds provided by FCT – Fundação para a Ciência e a Tecnologia

Cofinanciado por: COMPETE 2020 PROGRAMA OPERACIONAL COMPETITIVIDADE E INTERNACIONALIZAÇÃO; PORTUGAL 2020; UNIÃO EUROPEIA Fundo Europeu de Desenvolvimento Regional


2022 Ocean Surface Topography Science Team (OSTST) meeting | October 31 > November 4