

# PORTUGUESE SPACE ANALOGUES

CATALOGUE OF  
SITES AND FACILITIES



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CATALOGUE OF  
SITES AND FACILITIES

If you want to get in touch with any of the entities/  
authorities responsible for the activities, sites and/  
or infrastructure, **please contact the Portuguese  
Space Agency** via [del.esa.hre@ptspace.pt](mailto:del.esa.hre@ptspace.pt),  
hence the Agency will put both of you in touch.

Looking forward to hearing from you!

# An overview of Space Analogues in Portugal

Beyond addressing fundamental questions regarding the history of the universe, space exploration also promotes cutting-edge technology advancement, potentiates the use of extra-terrestrial resources, and fosters inspiration and international collaboration. This landscape is evolving rapidly in our modern society. From new public agencies and private players pursuing human space flight activities to new research and manufacturing capabilities carried out in LEO, the volume and complexity of space activities are increasing exponentially. Nonetheless, even though the costs of access to space are decreasing, this domain continues to be significantly capital expensive. Hence, the need to answer to research requirements and de-risk technologies in a more accessible manner has been giving rise to an interest in space analogue facilities and sites across the globe.

Portugal is a new player in the space exploration sector, but since the publication of the national space strategy in 2018, it has witnessed a growing scientific and industrial interest in specific space analogue sites in the country. To further develop space exploration, the Portuguese Space Agency initiated in 2022 an in-depth exercise to harmonize and consistently categorize existing and potential sites and facilities countrywide, with a particular interest in locations that offer complementary features to existing sites worldwide. For instance, Madeira and especially the Azores archipelagos hold the potential to carry out distinctive analogue activities in locations such as Selvagens islands, Capelinhos volcano, or in the Atlantic ocean by doing research, for example, around underwater hydrothermal vents.

Albeit shedding a light at a national level, it is paramount to consider a global and wide perspective by fostering collaboration and resource optimization in order to achieve common goals. Consequently, the effort carried out in Portugal builds upon the extensive experience of national and international experts and relies on the knowledge that other space agencies share via fora such as ISECG. A first deliverable of this exercise is the issue of the Portuguese Space Analogue Catalogue. This publication will become a steppingstone to promote future space analogue activities in the country in international cooperation.

This catalogue presents the main cross-cutting features of space analogue sites and facilities in Portugal and a way forward to promote their utilization for the benefit of all.

# INDEX

## NATIONAL ACTIVITIES

- 12 **NASA activities at Capelinhos volcano**  
by NASA
- 13 **ESA AVERT**  
by Spin.Works
- 14 **ISRU on MARS:  
Plasma conversion of CO<sub>2</sub> from the Martian atmosphere**  
by IST
- 15 **Microceno Project**  
by the University of Évora
- 16 **From Earth to Space**  
by Santa Maria Elementary and Secondary School, Azores
- 17 **ESA AITIVE**  
by Spin.Works
- 18 **Astronaut for a day**  
by the Portuguese Space Agency
- 19 **CAMões Research Mission**  
by Associação Os Montanheiros and INESC TEC

# STIES

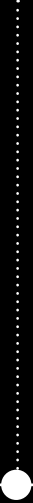
- 24 Barreiro da Faneca  
"The Red Desert"
- 26 Capelinhos Volcano
- 28 Mining Gallery G1
- 30 Natal Cave
- 32 Pico Volcano Crater  
Pico Mountain Observatory (OMP)
- 34 Selvagem Grande Island

# FACILITIES

- 40 ALterG
- 41 Tilt table
- 42 European Shock-Tube for High Enthalpy  
Research (ESTHER)
- 43 Low Temperature and High Magnetic Field  
Laboratory (LTHMFL)
- 44 Microwave plasma reactor
- 45 Ionizing Radiation Facilities Laboratory (IRIS)
- 46 Proton Beam Line Irradiation Facility (ICNAS)

1994 | 2019

2021



2015 | 2019

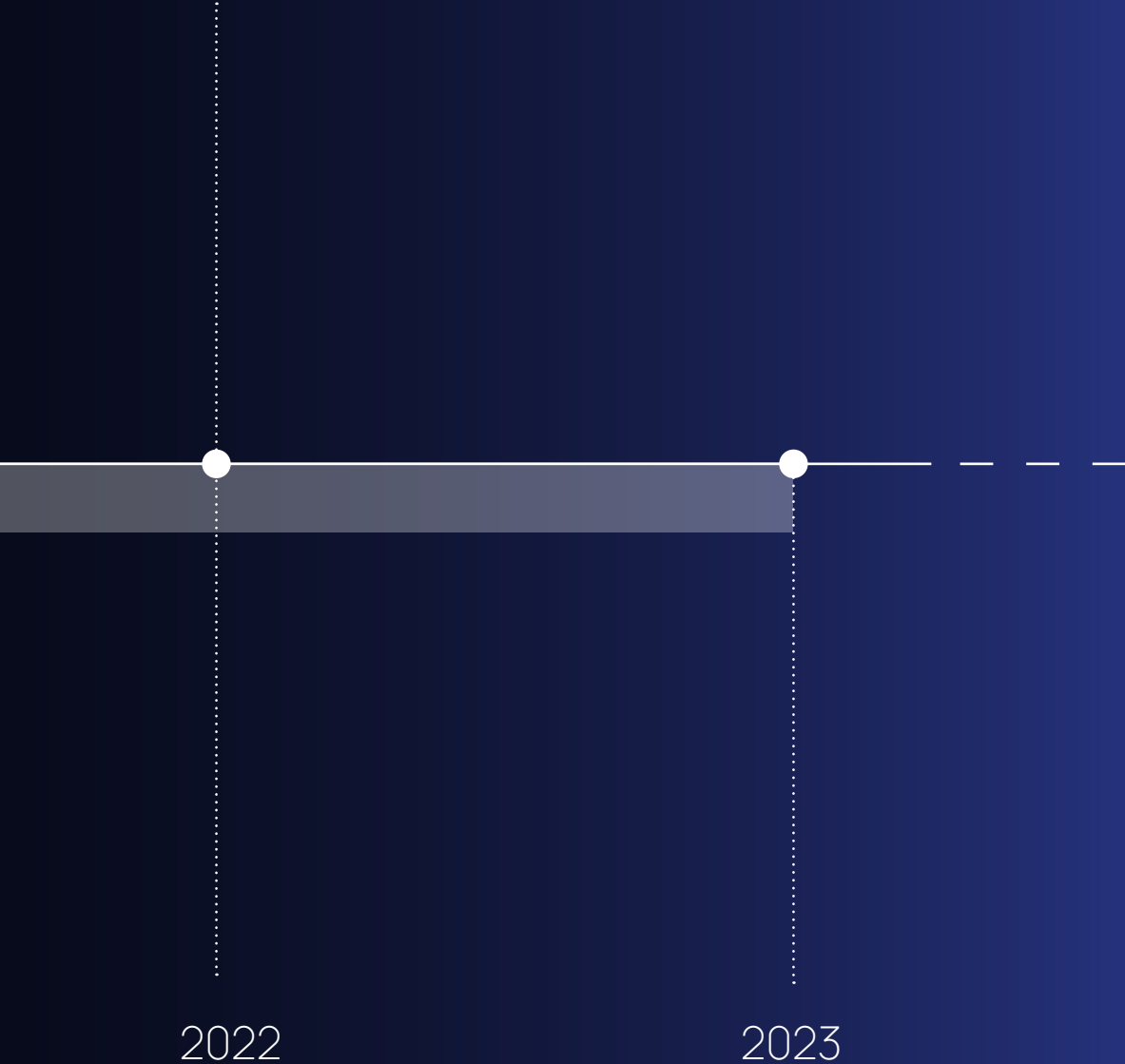


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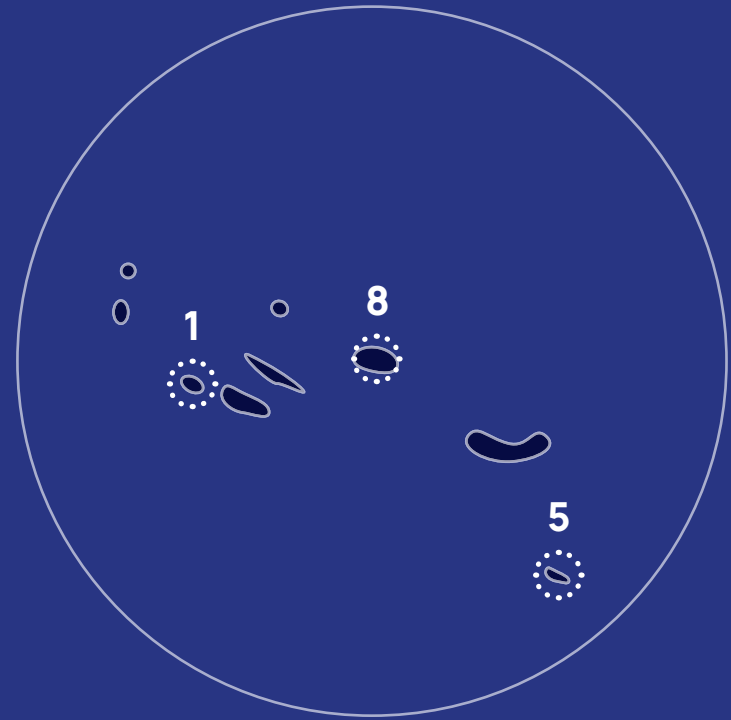
2021 - 2023

2022 | 2023 | 2024



# NATIONAL ACTIVITIES

Azores

**1 NASA – Capelinhos volcano**

Faial island, Azores

**2 ESA AVERT**

Calbrita quarry, Alenquer

**3 ISRU on Mars**

Campus Tecnológico e Nuclear, Lisboa

**4 Microceno Project**

Selvagem Grande, Madeira

**5 From Earth to Space**

Santa Maria, Azores

**6 ESA AITIVE**

Praia da Rainha, Cascais

**7 Astronaut for a day**

Beja

**8 CAMões Research Mission**

Natal Cave, Terceira Island, Azores



# NASA activities at Capelinhos volcano, Faial island, Azores



© Rui Amaro



1994, 2019



Faial Island  
Azores

Entity

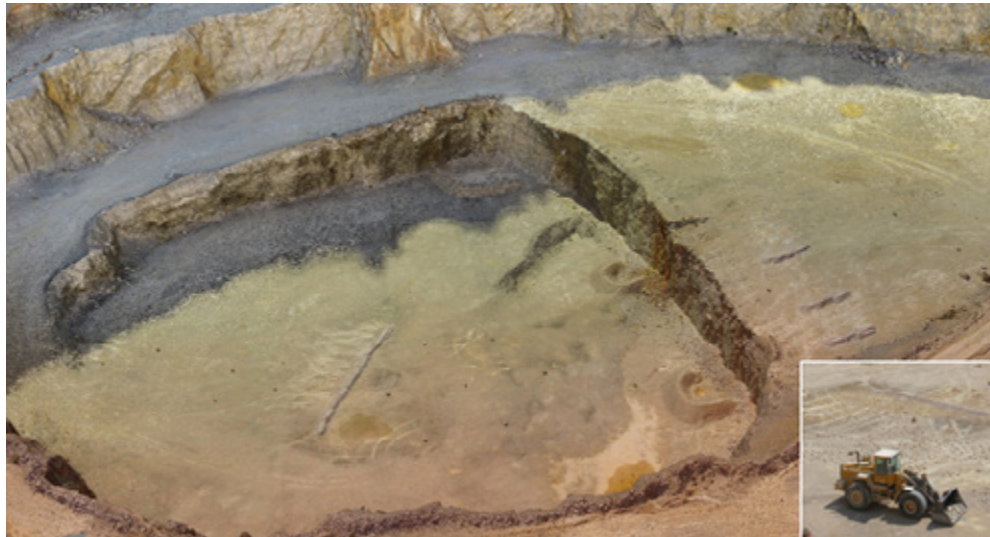
NASA

In 1994, within the NASA Earth and Planetary Science programs, and as part of testing new multi-beam airborne Light Detection And Ranging (LiDAR) instruments under design for spaceborne applications, NASA used Capelinhos volcano as a test mapping site to airborne geodetic LiDAR altimeter via systems deployed at the Azores. This impacted the design of multiple satellites such as the Global Ecosystem Dynamics Investigation (GEDI; now flying on the International Space Station (ISS)), the Ice, Cloud and land Elevation Satellite (ICESat-2 in Low Earth Orbit) and the Lunar Orbiter Laser Altimeter (LOLA, a Moon mapping satellite).

More recently, in 2019, another NASA activity took also place in Capelinhos volcano, to test drone-based digital elevation model (DEM) geodetic precision that can be correlated in time to DEM's computed from stereo satellite images (e.g., commercial imaging systems), in addition to interferometric synthetic aperture radar (SAR) imagery. This project included datasets of satellite-based topography as DEMs (from 2004 until 2022) and included recent drone mapping (2019) with structure-from-motion techniques (sampling topography at 8 cm scales) combined with ancillary satellite-based data (e.g., Radarsat-2 and Radarsat Constellation Mission SAR, ICESat-2 LiDAR, and some partial GEDI LiDAR).

In the future, NASA expects to monitor Capelinhos volcano by the NASA-ISRO Synthetic Aperture Radar (NISAR) mission (launching in 2024) as well as via commercial sub-meter imaging datasets (e.g., Maxar Technologies, Umbra, ICEYE, Capella Space) and experimentally via RADARSAT Constellation Mission (RCM).

# ESA AVERT by Spin.Works



© Spin.Works



2015, 2019

Calbrita quarry  
Alenquer

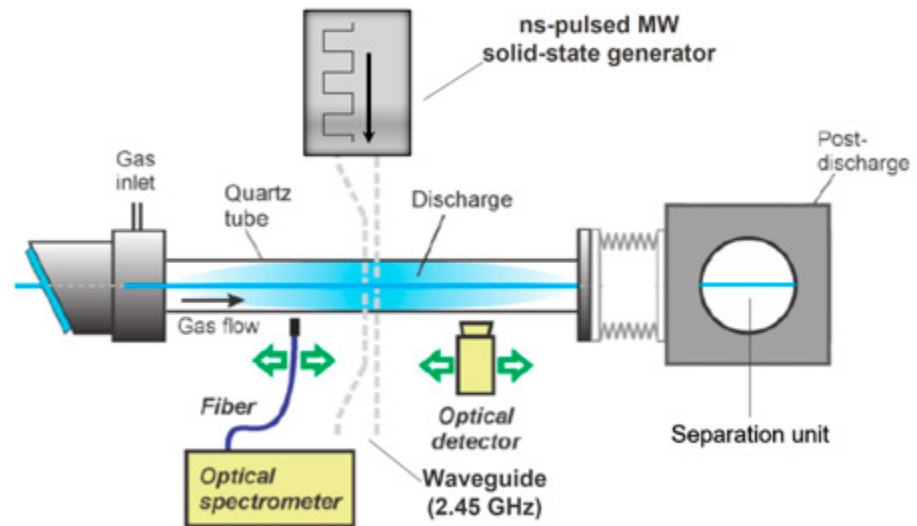
Entity Spin.Works

Within ESA Space Exploration Programme, the Portuguese aerospace company Spin.Works performed a set of tests of planetary landing systems based on imagery and scanning LiDAR - AVOIDANCE algorithms Extended development and Realistic Testing (ESA AVERT). To prepare for the testing, numerical tools were developed to simulate the dynamics of a landing module similar to the Exomars entry and descent module (EDM), as well as its sensors and control systems. A drone was also equipped with an inertial measurement unit (optic fibre), a laser altimeter, a visual camera and a scanning LiDAR system, whose technical specifications were selected to be as close as possible to those of a real mission.

For this activity, the chosen site for the testing was an area of the Calbrita temporarily inactive quarry, within the Alenquer region (Central West of Portugal), which was modified to become an environment analogue to the Mars surface. Initially, stones were distributed irregularly with the distribution and size representative of what is expected in typical landing sites. Additionally, sand was also dumped (in other sectors of the 120 x 120m<sup>2</sup> terrain) to simulate the dunar structures.

Following this, a flight was carried out with Spin.Works' drones equipped with high-resolution cameras, which allowed the accurate (with <5 cm resolution) reconstruction of the entire terrain, and which was then used as a reference for the testing of their systems. Finally, a set of tests was carried out with about 600 data acquisition sequences, which allowed to achieve the TRL5 of the systems of visual navigation and automatic obstacle detection and avoidance.

# ISRU on Mars: Plasma conversion of CO<sub>2</sub> from the Martian atmosphere by Instituto Superior Técnico



© IST



2021



Campus Tecnológico e Nuclear  
Loures

Entity

Institute for Plasmas and Nuclear Fusion (IPFN)

CO<sub>2</sub> is abundant in the Martian atmosphere and can be converted in-situ into oxygen (O<sub>2</sub>) and carbon monoxide (CO). Both CO and O<sub>2</sub> can be used in a propellant mixture, while O<sub>2</sub> can be collected and made available for breathing. The only on-site demonstration for O<sub>2</sub> production on Mars to date is the NASA's Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE), which is based on solid electrolysis cells (SOEC). The In-Situ Resource Utilization (ISRU) on Mars project, by Técnico proposes a new and complementary approach, linking two emerging technologies: non-thermal plasmas and ion-conducting membranes to decompose CO<sub>2</sub> directly from the Martian atmosphere and separate the products of CO<sub>2</sub> dissociation, respectively.

Non-thermal plasmas can be readily ignited at Martian ambient pressure and are expected to perform very well in terms of O<sub>2</sub> production per hour per kg of material sent to Mars. Other very strong points in favour of plasma technologies are that they are compact, scalable, do not require the use of expensive materials, and can instantaneously start and stop operation, being thus perfectly adapted to a power supply from intermittent photovoltaic energy sources. The conjunction of plasmas with the solid oxide membrane allows the direct separation of the conversion products, has enhanced durability, and brings cost reduction.

The knowledge acquired to develop ISRU for production of propellants and life support commodities on Mars will also make life on Earth more productive, clean and sustainable. It will contribute to improve CO<sub>2</sub> utilization technologies on Earth, fostering the transition to renewable energy.

# Microceno Project by the University of Évora



© Ana Zélia Miller



2021



Selvagem Grande  
Madeira

Entity University of Évora

The Microceno research project <sup>[1]</sup>, led by the University of Évora and funded by the Portuguese Foundation for Science and Technology (FCT), aims at investigating the microbiology and mineralogy of the volcanic caves of the remote Selvagens Islands (Madeira archipelago, Portugal). The expedition to Selvagens involved 17 researchers from 7 countries. This multidisciplinary team recognized and identified known and new caves at Selvagens, documenting additional 10 cavities and discovering one new important cave, Furna do Sopro do Dragão (Selvagem Grande). The geological survey involved creating the first high-resolution three-dimensional models of the caves from Selvagem Grande and allowed it to be considered an analogue of Mars. The characterization of highly complex subsurface microbial communities adapted to pristine caves and their interactions with biotic and abiotic factors, will provide new insights into subsurface microbiology from a natural setting free of anthropogenic influence and into the adaptation and evolution of microbial life on Earth. The results may have significance for astrobiology and future planetary explorations <sup>[2]</sup>.

As an isolated and undisturbed ecosystem, these volcanic caves are interesting for the study of pristine biosignatures preserved in siliceous speleothems which also has interesting implications for potential karstic processes in volcanic environments on Mars where sedimentary dikes constituted by sulphates have been widely documented by satellite observations and ground rovers <sup>[2]</sup>.

This expedition included the usage of portable cutting-edge technology such as Unmanned Aerial Vehicle (UAV), laser scanner for three-dimensional mapping, portable scanning electron microscope, x-ray fluorescence equipment for the elemental characterization of rocks and minerals, and a portable deoxyribonucleic acid (DNA) sequencing system. This technology allowed identifying on-site a wide variety of mineral-utilizing microorganisms, such as chemolithoautotrophic bacteria, in less than 24h. These bacteria could serve as a model in the search for past microbial life that might have thrived in Mars lava tubes. This suite of instruments may be used in future Mars activities such as planetary caves exploration or in the detection of microbial life <sup>[3]</sup>.

[1] A. Z. Miller, J. M. de la Rosa, N. T. Jiménez-Morillo, Book of Abstracts of the 1st European Meeting on Geomicrobiology of Volcanic Caves, Seville, 2023.

[2] Palma et al., (2024). Connecting molecular biomarkers, mineralogical composition, and microbial diversity from Mars analog lava tubes. Science of the Total Environment 913, 169583.

[3] Titus TN, Wynne JJ, Malaska MJ, et al. (2021). A Roadmap for Planetary Caves Science and Exploration. Nature Astronomy, 5, 524–525.

# From Earth to Space by Santa Maria Elementary and Secondary School, Azores



© Escola Básica e Secundária de Santa Maria



2021 - 2023



Santa Maria Island  
Azores

Entity

Escola Básica  
e Secundária  
de Santa Maria

From Earth to Space project intends to bridge scientific knowledge and technology regarding space sciences and technologies with the local community of Santa Maria, Azores, while inspiring and motivating the youth (secondary and high school students, and teachers) towards sectors related to space, science and technology. The goal of this project is to simulate the landing of an astronaut on Mars, and it consists of 3 phases: 1) acquisition of the scientific and technological knowledge necessary for the mission simulation; 2) launch of an unmanned vehicle for technological validation and preparation for manned operations; 3) operations with crewed vehicles culminating in the landing of astronauts on Mars.

Among other components, this activity included a control room, the construction of a spaceship cockpit simulator a rover and space suits. The team built two spacesuits for extra-vehicular activities (EVA), which included 3D printed parts, based on the A7L from the Apollo missions, while the helmet was based on the Mercury space suit. It also included the construction of two intra-vehicular activity (IVA) survival suits, and a portable life support system (PLSS). With regards to the spaceship simulator, a panel was built based on the documentation for the Apollo Lunar Module, which included the attitude control joysticks and translation/thrust control assembly (TTCA). Beyond this, a rover launch was also simulated. Simultaneously, the students also produced posters regarding space exploration topics (e.g., human physiologic limits, the operation of spacesuits, astronaut's nutrition and space radiation).

This project culminated with the "astronaut walk" in a Martian landscape in Barreiro da Faneca, Santa Maria, also known as "red desert". Overall, it involved multiple entities such as NAV Portugal, Edisoft, Aireon, Portuguese Space Agency, and was sponsored by Atlantic Spaceport Consortium.

# ESA AITIVE by Spin.Works



© Spin.Works



2022



Praia da Rainha  
Cascais

Entity Spin.Works

Within ESA Space Exploration Programme, Spin.Works was involved in Artificial Intelligence Techniques for Guidance, Navigation & Control for Design, Implementation and Verification (AITIVE) project within which the company carried out flights over an area prepared for testing visual navigation systems. For this case, they built about 100 craters on a 50 x 50 m<sup>2</sup> sector in the Praia da Rainha area (Central West of Portugal) to be an analogue of Mars representative terrain, over which the company made a dozen flights using a proprietary camera that is now qualified to fly in space.

# Astronaut for a Day by Portuguese Space Agency



© Portuguese Space Agency / Air Zero G



2022, 2023, 2024



Beja  
Portugal

Entity

Portuguese  
Space Agency

The Zero-G Portugal – Astronaut for a day initiative is organized by the Portuguese Space Agency with support of other national entities and aims to disseminate and promote space among the younger generation through parabolic flights that create a microgravity environment that lasts few seconds. The selection of participants in this initiative includes 5 selection phases that emulate ESA's astronaut selection process: 1 – Registration and presentation, 2 – Space perception and interpretation, 3 – Physical fitness, 4 – Interview, 5 – Final phase. During the 3 days prior to the flight, the students participate in preparatory activities to learn about the flight details, develop their outreach skills and to get to know the other flight attendees. These students will become Astronaut for a Day ambassadors, as they are expected to convey this experience and learnings with their community in the months to follow. In 2022, 31 high school students (15 female, 16 male) experienced this flight, while in the second edition (10 females, 20 males) flew in September 2023.

# CAMões Research Mission by Associação Os Montanheiros and INESC TEC



© Mara Leite



2023



Natal Cave,  
Terceira Island  
Azores

Entity

Associação Os  
Montanheiros  
and INESC TEC

Caving Analog Mission for Ocean, Earth, and Space exploration (CAMões Mission) is a simulation of a Mars and Moon environment at Natal cave, a lava tube cave, at Terceira Island (Azores) [4]. This seven-day space research analogue experience with seven crew members involves five countries. This volcanic structure is relevant for space exploration studies due to its structural advantages such as protection from radiation, micrometeorites, extreme temperature variations, and potential for resource utilisation [5]. The selection of this site was based on criteria such as geology, prior knowledge, accessibility, geotechnical stability, geohazard assessment, safety, environmental and land use, management and local support from a speleology group, as well as natural conservation restrictions and concerns.

Portugal's first Lunar analog mission included 7 crew members (Crew Zero), 4 researchers in Mission Control, and 3 members of the Medical Team. Several entities and institutions were also involved in the CAMões mission, and the scientific goals included: 1) geohazard mapping towards safety and stability; 2) geophysical study on the feasibility of the lava tube structure; 3) microbiological science; 4) behavioral and human health science; 5) human physical habitability assessment; 6) crew resources management training; 7) education and outreach [6]. Overall, the team intends to contribute with data not only for the scientific objectives but also improving the site for future operational missions. This concept, in the future, may also be extended to other islands. [7].

[4] Montanheiros, Camões project, <http://www.montanheiros.com/camoesproject/>, (accessed 25.08.2023).

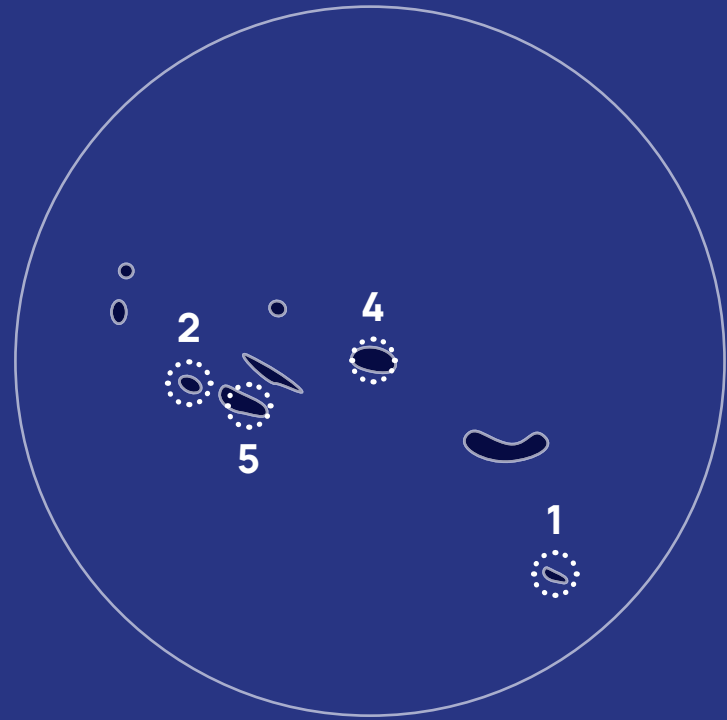
[5][6] Ana Pires; Rui Moura; Joao Carlos Nunes; Paulo Barcelos; Pedro Caetano; Pedro Quinteiro; Aiydi S. Gonzalez-Serricchio; Yvette Gonzalez; Slavka Andrejkovicova; Paul Niel; Helder I. Chamine (2023). Azorean lava tube systems: a proposal for a new planetary analog site towards future Lunar and Martian exploration research. In: Proceedings of the 3rd International Multidisciplinary Scientific GeoConference SGEM 2023 – Section Applied & Environmental Geophysics. doi.org/10.5593/sgem2023/11/s05.64

[7] Rui Moura; Ana Pires; Marina Cabral Pinto; Joao Carlos Nunes (2023). General characteristics of the Capelinhos Volcano (Azores Islands, Portugal) as a new planetary analog site aimed at space exploration research. In: Proceedings of the 3rd International Multidisciplinary Scientific GeoConference SGEM 2023 – Section Applied & Environmental Geophysics. doi.org/10.5593/sgem2023/11/s05.68



SITES

Azores



**1 Barreiro da Faneca “The Red Desert”**  
Santa Maria, Azores

**2 Capelinhos Volcano**  
Faial island, Azores

**3 Mining Gallery G1**  
Valongo, Porto

**4 Natal Cave**  
Angra do Heroísmo, Terceira Island, Azores

**5 Pico Volcano Crater,  
Pico Mountain Observatory (OMP)**  
Pico Island, Azores

**6 Selvagem Grande Island**  
Selvagem Grande Island, Madeira



# Barreiro da Faneca, “The Red Desert”



© Regional Government of the Azores



Barreiro da Faneca (200 m altitude) protected area, located at Santa Maria Island (Azores), is characterized by a thick layer of arid and clay soil. The landcover is characterized by thin piroclasts (lapilli and ash).



250 x 600 m<sup>2</sup>

The topography of this sector is characterized as being flat with a slightly undulating relief, very gentle slopes and very low drainage density. In the barren areas, there are dune accumulations promoted by aeolian erosion<sup>[8]</sup>. It can be easily accessed by road.

[8] J. C. Nunes, E. A. Lima, S. Medeiros, Os Açores, Ilhas de Geodiversidade: O Contributo da Ilha de Santa Maria, AÇOREANA (2007) Supl. 5: 74-111.

Altitude	Geology features and Topography	Biology features	Geology and Biology Sampling
215 m	Thick layer of arid and clay soil; thin piroclasts (lapilli and ash). In the barren areas, there are dune accumulations promoted by aeolian erosion. Flat with a slightly undulating relief, very gentle slopes and very low drainage density.	N/A	Subject to prior authorization
Pristine	Climate	Site well drained and not subject to flooding	
No	Low temperature range and high rainfall and humidity (strong oceanic influence)	N/A	

Area restrictions	Authority responsible	Terrain modifications	Planetary body analogue
Santa Maria Natural Park: Protected Landscape of Barreiro da Faneca	Regional Government of the Azores (Regional Secretariat for the Environment and Climate Change)	To be confirmed with the responsible authority	Mars

Logistics	Accessibility	Date restrictions	Maximum crew capacity	Existing infrastructure
	Easily accessed by road	N/A	N/A	Close to small villages
	Distance to places to obtain supplies	Power supply		Shipping
	5 Km	No		Yes

Communication	Cell phone voice coverage	Health and hazards	Distance to the closest medical facilities
	NA		≈ 7 Km
Communication	Cell phone data coverage	Health and hazards	Environmental hazards
	N/A		N/A

Degree of difficulty for Rover	Variety of obstacles that can be navigated by a rover	Worksite slopes less than 15°
	Yes	Yes

# Capelinhos Volcano



© INESC TEC



Capelinhos volcano is located at the westernmost part of Faial island (with 21 km length and 173 km<sup>2</sup>), which is one of the nine islands that composes the Azores archipelago in the North Atlantic Ocean.

0.3 km<sup>2</sup>

Due to its recent eruptive origin (1957-58) the landscape in the volcano is barren. The eruption that generated this volcanic structure was composed by two main phases: an initial submarine (or surtseyan) phase, characterized by the emission of mostly volcanic ash and sea water vapor, with high eruptive columns, sometimes with the formation of pyroclastic surges, followed by a subaerial phase with alternating more or less explosive periods, with the emission of lapilli, bombs and blocks and some effusive periods, with the extrusion of lava flows <sup>[9]</sup>. These subaerial eruptive features (scoria cones, ashfall deposits, palagonitized cliffs and playas in saddle areas) are considered by NASA as offering multiple planetary analogue landscape and compositional features with direct relevance to possible surtseyan type eruptions on Mars (e.g. as in *Nepenthes Mensae*) during prior eras on Mars (when surface waters were extant). In addition, other entities have also considered these structures as relevant analogues of other planetary bodies such as the Moon. Nevertheless, this site does not have impact features.

The surrounding topography allows for vehicle testing and locomotion in various slope and granulometric ground conditions <sup>[10]</sup>. Additionally, there is ease of access to Capelinhos volcano and also ease to operate and support space analogue research missions for both human and robotic missions. Namely, in terms of accessibility, there is an easy road access and recurrent flights between the Azorean islands, as well as with Portugal's mainland. Lastly, this natural structure is within Faial Island Natural Park: Capelinhos Volcano Natural Monument.

[9][10] Rui Moura; Ana Pires; Marina Cabral Pinto; Joao Carlos Nunes (2023). General characteristics of the Capelinhos Volcano (Azores Islands, Portugal) as a new planetary analog site aimed at space exploration research. In: Proceedings of the 3rd International Multidisciplinary Scientific GeoConference SGEM 2023 – Section Applied & Environmental Geophysics. doi.org/10.5593/sgem2023/1.1/s05.68

Altitude	Geology features and Topography	Biology features	Geology and Biology Sampling
40 m	Scoria cones, ashfall deposits, palagonitized cliffs and playas in saddle areas. Barren soil.	N/A	Subject to prior authorization
Pristine	Climate	Site well drained and not subject to flooding	
No	Low temperature range and high rainfall and humidity (strong oceanic influence)	N/A	

Area restrictions	Authority responsible	Terrain modifications	Planetary body analogue
Faial Island Natural Park: Capelinhos Volcano Natural Monument	Regional Government of the Azores (Regional Secretariat for the Environment and Climate Change)	To be confirmed with the responsible authority	Mars, Moon

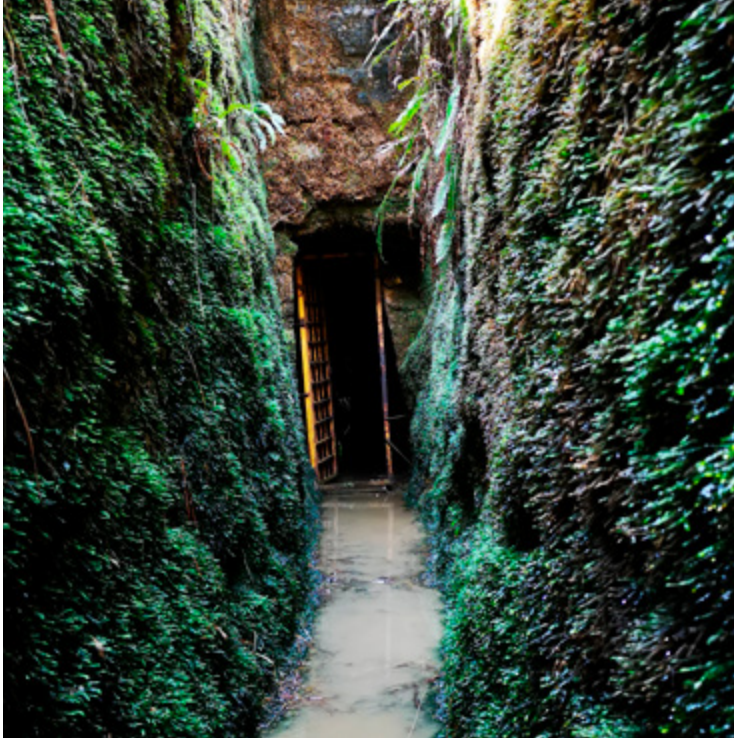
Logistics	Accessibility	Date restrictions	Maximum crew capacity	Existing infrastrucutre
	Easily accessible road and recurrent flights between the Azorean islands, as well as with Portugal's mainland.	N/A	N/A	Yes, Capelinhos Volcano Interpretation Centre
	Distance to places to obtain supplies	Power supply		Shipping
~30 Km	No		Yes	

Communication	Cell phone voice coverage
	NA
Communication	Cell phone data coverage
	N/A

Health and hazards	Distance to the closest medical facilities
	~30 Km
Health and hazards	Environmental hazards
	N/A

Degree of difficulty for Rover	Variety of obstacles that can be navigated by a rover	Worksite slopes less than 15°
	Yes, to be confirmed with the responsible entity	Depends

# Mining Gallery G1



© Câmara Municipal de Valongo



In the North of Portugal, the roman mining cavities set an isolating environment, which could be ideal for conduct technology testing and analysis of human behaviour in isolated and confined environment. Gallery G1 is an old drainage gallery of the Mining Roman Complex of Fojo das Pombas, measuring approximately 135 meters. The first part of the trail is suitable for visitors and develops between the entrance and 116 meters. Along this track there are three vertical shafts (P6, P17 and P25) that were used for ventilation and possible removal of material. <sup>[11]</sup> <sup>[12]</sup>



116 m

[11] MineHeritage EU Project ([mineheritage-project.eu/](http://mineheritage-project.eu/))

[12] MineHeritage Booklet - Valongo Mine ([mineheritage-project.eu/rest/booklet/10120005](http://mineheritage-project.eu/rest/booklet/10120005))

Altitude	Geology features and Topography	Biology features	Geology and Biology Sampling
211 m	1 water drainage gallery	N/A	N/A
Pristine	Climate	Site well drained and not subject to flooding	
No	Outside of the gallery: Temperate, temperature throughout the year varies from 5 °C to 25 °C (with Atlantic and Mediterranean influences)	Usually with water, depending on the time of the year	
Area restrictions	Authority responsible	Terrain modifications	Planetary body analogue
Narrow gallery, visits for groups of 4 to 5 people at a time, currently with no security exit.	Municipality of Valongo	Only mobilization of surface land for reforestation.	Isolated and confined environment, which could be ideal for conduct technology testing and analysis of human behaviour.

Logistics	Accessibility	Date restrictions	Maximum crew capacity	Existing infrastrucutre
	Easily accessed by road	N/A	N/A	Close to a city
	Distance to places to obtain supplies		Power supply	Shipping
	≈ 2 Km		N/A	Yes

Communication	Cell phone voice coverage
	NA
	Cell phone data coverage
	N/A

Health and hazards	Distance to the closest medical facilities
	≈1 Km
	Environmental hazards
	N/A

Degree of difficulty for Rover	Variety of obstacles that can be navigated by a rover	Worksite slopes less than 15°
	N/A	Yes

# Natal Cave



© Associação Os Montanheiros



The Natal cave in Terceira Island (Azores) is a lava tube structure originated due to the effusive volcanic episodes. There are several lava tubes scattered across the region <sup>[13]</sup>. This cave has a 696.6 m long, 12 m wide and 7 m high lava tube <sup>[14]</sup>, with several ramifications. It contains multiple speleothems such as lava stalactites and stalagmites, flow marks and levées.



697 m long

[13] Ana Pires; Rui Moura; Joao Carlos Nunes; Paulo Barcelos; Pedro Caetano; Pedro Quinteiro; Aidyl S. Gonzalez-Serricchio; Yvette Gonzalez; Slavka Andrejkovicova; Paul Niel; Helder I. Chamine (2023). Azorean lava tube systems: a proposal for a new planetary analog site towards future Lunar and Martian exploration research. In: Proceedings of the 3rd International Multidisciplinary Scientific GeoConference SGEM 2023 – Section Applied & Environmental Geophysics. doi.org/10.5593/sgem2023/11/s05.64

[14] Pereira, F., J.C. Nunes, P.A.V. Borges, M.P. Costa, J.P. Constância, P.J.M. Barcelos, t. Braga, r. Gabriel, i.R. Amorim, e.A. Lima, p. Garcia e s. Medeiros, 2015. Catálogo das Cavidades Vulcânicas dos Açores (Grutas Lávicas, Algarés e Grutas de Erosão Marinha) - Catalogue of the Azorean Caves (Lava Tube Caves, Volcanic Pits, and Sea-erosion Caves). Os Montanheiros/GESPEA (Ed.). Edição on-line.

Altitude	Geology features and Topography	Biology features	Geology and Biology Sampling
522 m	Lava tube structure. This cave has a 696.6 m long, 12 m wide and 7 m high lava tube, with several ramifications. It contains multiple speleothems such as lava stalactites and stalagmites, flow marks and levées.	N/A	Subject to prior authorization
Pristine	Climate	Site well drained and not subject to flooding	
No	Low temperature range and high rainfall and humidity (strong oceanic influence)	N/A	

Area restrictions	Authority responsible	Terrain modifications	Planetary body analogue
Terceira Island Natural Park: Nature Reserve of Serra de Santa Bárbara and Mistérios Negros. Legal framework for the protection and classification of volcanic caves of the Azores	Regional Government of the Azores (Regional Secretariat for the Environment and Climate Change) and Association Os Montanheiros	To be confirmed with the responsible authority.	Mars

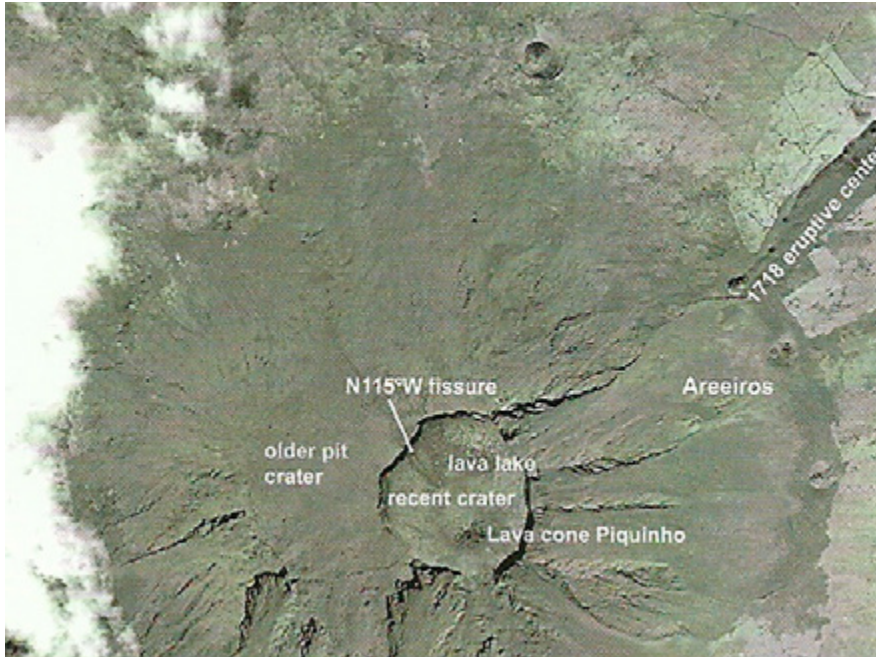
Logistics	Accessibility	Date restrictions	Maximum crew capacity	
	Easily accessed by road, carferry to arrive to the island, closest airport at Terceira island	N/A	N/A	
	Existing infrastrucutre	Distance to places to obtain supplies	Power supply	Shipping
	Yes, Natal Cave Interpretation Centre	≈13 Km	N/A	Yes

Communication	Cell phone voice coverage
	NA
Cell phone data coverage	N/A

Health and hazards	Distance to the closest medical facilities
	≈12 Km
Environmental hazards	N/A

Degree of difficulty for Rover	Variety of obstacles that can be navigated by a rover	Worksite slopes less than 15°
	N/A	N/A

# Pico volcano crater, Pico Mountain Observatory (OMP)



© Research Institute for Volcanology and Risk Assessment



Located in Madalena, Pico island in the Azores, the volcanic crater at an altitude of about 2250 m above sea level with 550 m of diameter and limited in its perimeter by slopes and cliffs as high as 30 m in the W and E borders, while at the northeast side emerges a lava cone with 125 m-high, reaching an altitude of 2351 m above sea level.



550 m of diameter and limited in its perimeter by slopes and cliffs as high as 30 m in the W and E borders

Related to eruptive fissure in the bottom of the crater, the volcanic deposits that are identified range from basaltic lava flows to basaltic pyroclastic deposits. Moreover, the existing fumaroles contain potential for the existence of extremophile organisms. The vegetation is of low density and of the extreme alpine type.

This site has potential for testing both technology and human related activities and can work as analogue planetary bodies Mars and Moon.

<b>Altitude</b>	<b>Geology features and Topography</b>	<b>Biology features</b>	<b>Geology and Biology Sampling</b>
2250m (crater)	Volcanic deposits ranging from basaltic lava flows to basaltic pyroclastic deposits.	Existing fumaroles contain potential for the existence of extremophile organisms. The vegetation is of low intensity and of the extreme alpine type.	Subject to prior authorization
<b>Pristine</b>	<b>Climate</b>		<b>Site well drained and not subject to flooding</b>
No	Temperate with no dry season with a short and cool summer or Subpolar oceanic climate (Cfc - Köppen climatic classification). Late Autumn and Winter is covered by a layer of ice and is prone to strong winds, with some gusts reaching 200 km/h.		Yes
<b>Area restrictions</b>	<b>Authority responsible</b>	<b>Terrain modifications</b>	<b>Planetary body analogue</b>
Pico Island Natural Park: Pico Mountain Nature Reserve	Regional Government of the Azores (Regional Secretariat for the Environment and Climate Change)	To be confirmed with the responsible authority. This site has potential for testing both technology and human related activities.	Mars, Moon

<b>Logistics</b>	<b>Accessibility</b>	<b>Date restrictions</b>	<b>Maximum crew capacity</b>	
	The access road from sea level to the mountain house at 1200 m altitude (beginning of the pedestrian trail) has sections with inclinations that can reach around 25°. Nearest airport is around 16 km. Trail of about 3 km, with a muddy start when it rains and with some vegetation (up to 1 m), as you go up it becomes rocky (scarce vegetation), with parts with loose rocks, general trail with steep slope.	Environmental safety restrictions to hike due to climateric conditions.	N/A	
	<b>Existing infrastrucutre</b>	<b>Distance to places to obtain supplies</b>	<b>Power supply</b>	<b>Shipping</b>
	OMP equipped with sensor for atmospheric measurements (aerosols, some gases, metereological parameters)	20 Km	Yes but limited	Yes

<b>Communication</b>	<b>Cell phone voice coverage</b>
	NA
	<b>Cell phone data coverage</b>
	OMP has limited WiFi internet

<b>Health and hazards</b>	<b>Distance to the closest medical facilities</b>
	Civil protection removal
	<b>Environmental hazards</b>
	Extreme temperature variations between day and night, high UV levels.

<b>Degree of difficulty for Rover</b>	<b>Variety of obstacles that can be navigated by a rover</b>	<b>Worksite slopes less than 15°</b>
	Yes	Yes

# Selvagem Grande Island



© Ana Zélia Miller



2.4 km<sup>2</sup>

Isolated and uninhabited island of volcanic origin, Selvagem Grande Island (2.4 km<sup>2</sup>) belongs to the Nature Reserve of Selvagens Islands, achieving an altitude of 163 m above sea level. On the one hand, geomorphologically characterized by an extensive plateau at around 100 m above sea level surrounded by sheer cliffs, while geologically it consists of basaltic lava and carbonate dykes and it is located in a zone of slow tectonic plate movement, which resembles the geological processes that occur on the red planet, where there is no continental drift, which makes it a great terrestrial analogue to Martian geology. On the other hand, the presence of extremophiles, such as chemolithotrophic bacteria and archaea in caves and salt pools, makes it interesting for astrobiology, beyond the detection of novel microbial species, unique and rare on a global scale due to its pristine ecosystems.

Altitude	Geology features and Topography	Biology features
100 m up to 163 m	Extensive plateau at around 100 m above sea level surrounded by sheer cliffs, consisting of basaltic lava and carbonate dykes. Located in a zone of slow tectonic plate movement, which resembles the geological processes that occur on Mars.	Presence of extremophiles, such as chemolithotrophic bacteria and archaea in caves and salt pools. Novel microbial species, unique and rare on a global scale due to its pristine ecosystems.

Geology and Biology Sampling	Pristine	Climate	Site well drained and not subject to flooding
Yes, rocks, sediments and speleothems, microbial mats, subsurface microorganisms	Yes	Subtropical desert climate	No

Area restrictions	Authority responsible	Terrain modifications	Planetary body analogue
Nature Reserve of Selvagens Islands	Institute for Nature Conservation and Forests (ICNF)	To be confirmed with the responsible authority.	Mars

Logistics	Accessibility	Date restrictions	Maximum crew capacity	
	No terrain trafficability, about 280 km from Madeira Island. Nearest airport is at Madeira island. Trails are difficult with high slope.	Yes, during sea birds nesting seasons (sensitive growth periods)	10	
	Existing infrastrucutre	Distance to places to obtain supplies	Power supply	Shipping
	Refuge from the nature reserve	Thousands of kms	Yes	No

Communication	Cell phone voice coverage
	No
	Cell phone data coverage
	N/A

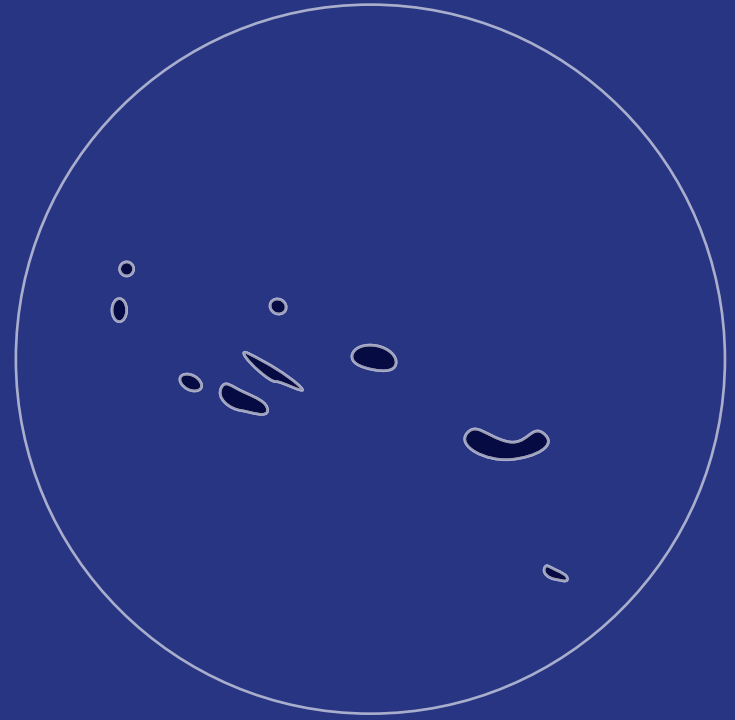
Health and hazards	Distance to the closest medical facilities
	280 km by boat
	Environmental hazards
	Yes, ciguatera

Degree of difficulty for Rover	Variety of obstacles that can be navigated by a rover	Worksite slopes less than 15°
	Yes	Yes



# FACILITIES

Azores

**1 AlterG**

Lisbon

**1 Tilt table**

Lisbon

**1 Microwave plasma reactor**

Lisbon

**2 European Shock-Tube for High Enthalpy Research (ESTHER)**

Loures, Lisbon

**2 Low Temperature and High Magnetic Field Laboratory (LTHMFL)**

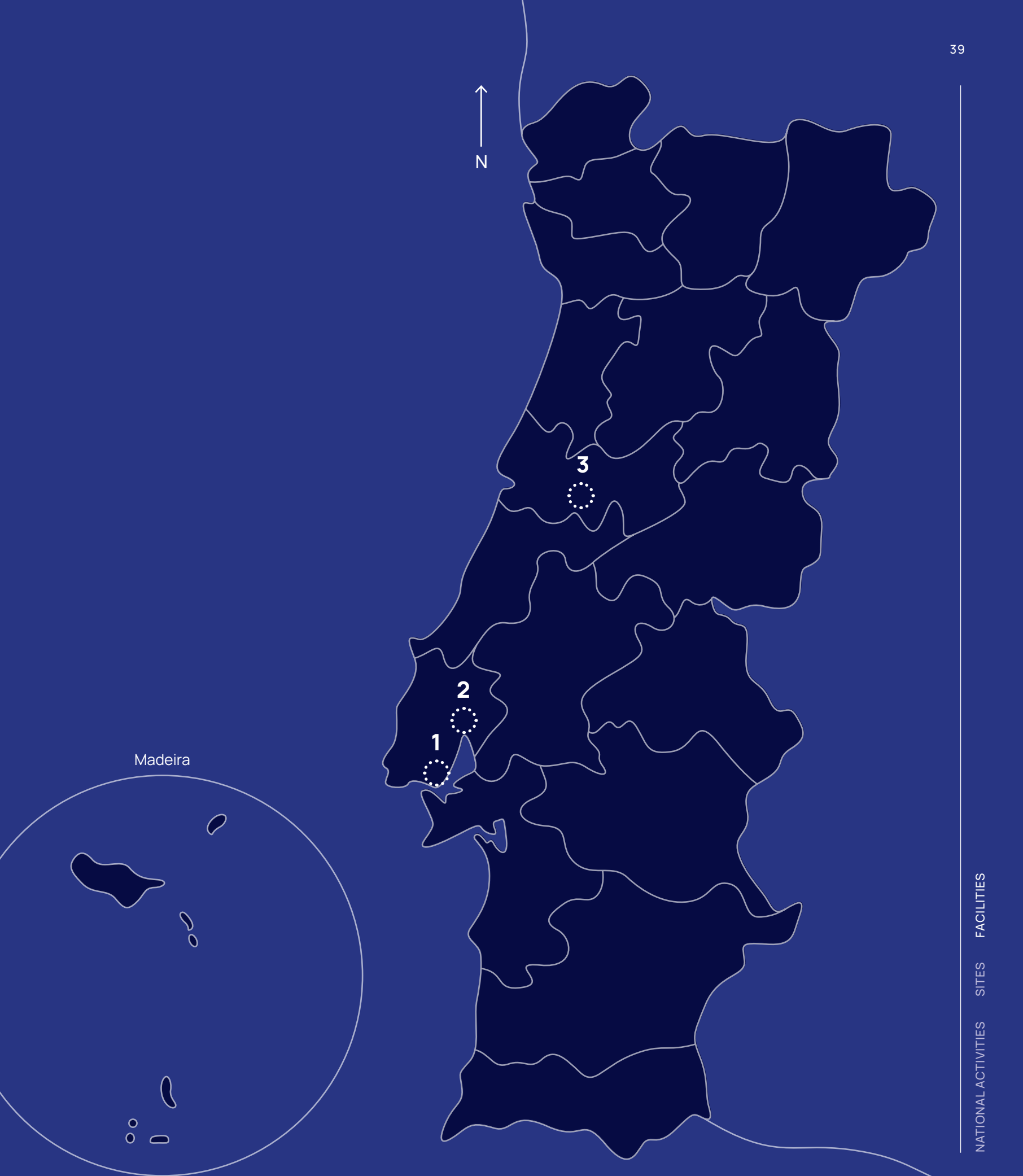
Loures, Lisbon

**2 Ionizing Radiation Facilities Laboratory (IRIS)**

Loures, Lisbon

**3 Proton Beam Line Irradiation Facility (ICNAS)**

Coimbra



Madeira

# AlterG



Lisbon



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## Study Field

Human

## Entity

Medical facilities, Centre for Aerospace Medicine Studies (CEMA)  
University of Lisbon,  
Lisbon

## Organization

Centre for Aerospace  
Medicine Studies  
(CEMA)

Alter G equipment allows testing the human body under reduced impact and gravitational forces during mobility activities, by studying the changes of ways of walking the human organism in lower gravity levels. The equipment simulates hike and run in environments with lower gravity, such as Moon or Mars. As first step to use the equipment it is necessary the use of specific shorts connected to the machinery to simulate the gravity alteration waist down. These features allow testing the human body under reduced impact and gravitational forces during mobility activities.

# Tilt table



Lisbon



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## Study Field

Human

## Entity

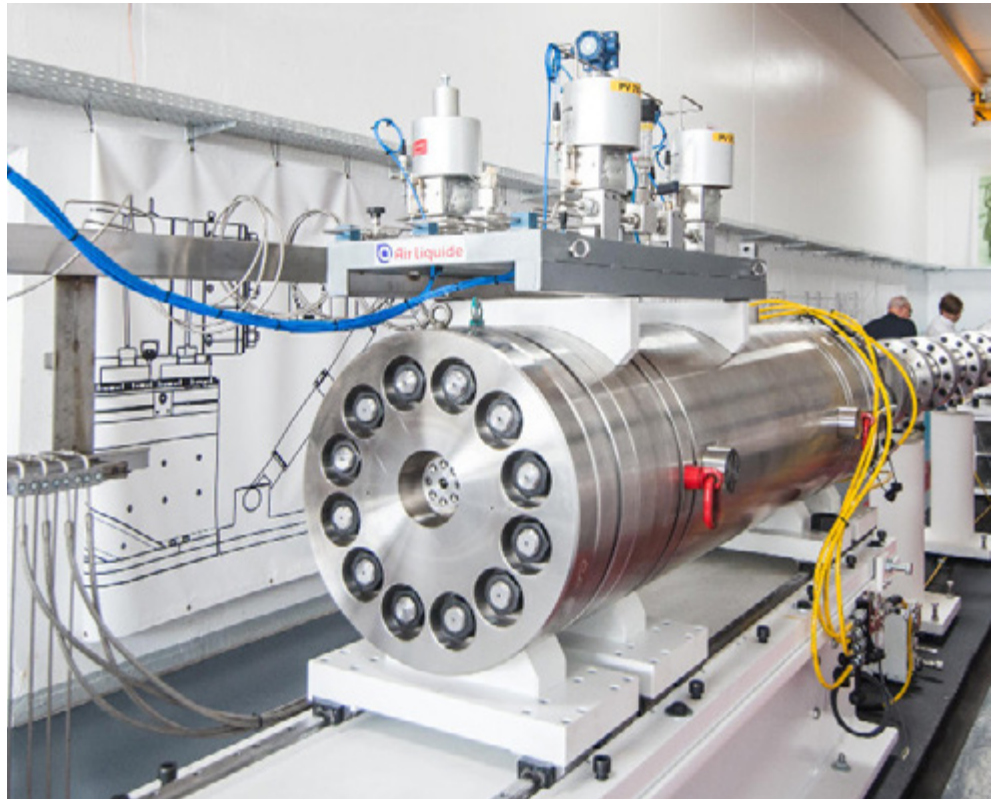
Medical facilities, Centre for Aerospace Medicine Studies (CEMA)  
University of Lisbon,  
Lisbon

## Organization

Centre for Aerospace  
Medicine Studies  
(CEMA)

Tilt table resembles a stretcher, where the person lays down and the head can be settled at six negative degrees, increasing the blood pressure in this part of the body as a result of the blood distribution similar to a non-gravity space environment. This way it is possible to study physiological alteration and ways of the organism to adapt. In some cases, volunteers stay in this position up to one month. At CEMA studies are done at eye and jugular level via a probe.

# European Shock-Tube for High Enthalpy Research (ESTHER)



Loures

## Study Field

Physical

## Entity

Institute for Plasmas and Nuclear Fusion (IPFN)  
 Instituto Superior Técnico,  
 University of Lisbon,  
 Loures

## Organization

Institute for Plasmas and Nuclear Fusion (IPFN)

The European Shock-Tube for High Enthalpy Research (ESTHER), unique in the Europe, aims to reproduce the conditions of an atmospheric entry at the ground level being able to achieve shock velocities between 3 and 20 km/s and a large number of shots per day. This capability is crucial to support the design of thermal protection systems, which is essential for future planetary missions, by simulating entries into other planet atmosphere, and for return missions to Earth. It is composed of a two-stage combustion-driven shock tube and assorted instrumentation (optical spectroscopy and microwave interferometry) which allows the simulation of high enthalpy plasma physics for different gas mixtures that is essential for complex numerical modelling designs of thermal protection systems.

# Low Temperature and High Magnetic Field Laboratory (LTHMFL)



Loures



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## Study Field

Physical

## Entity

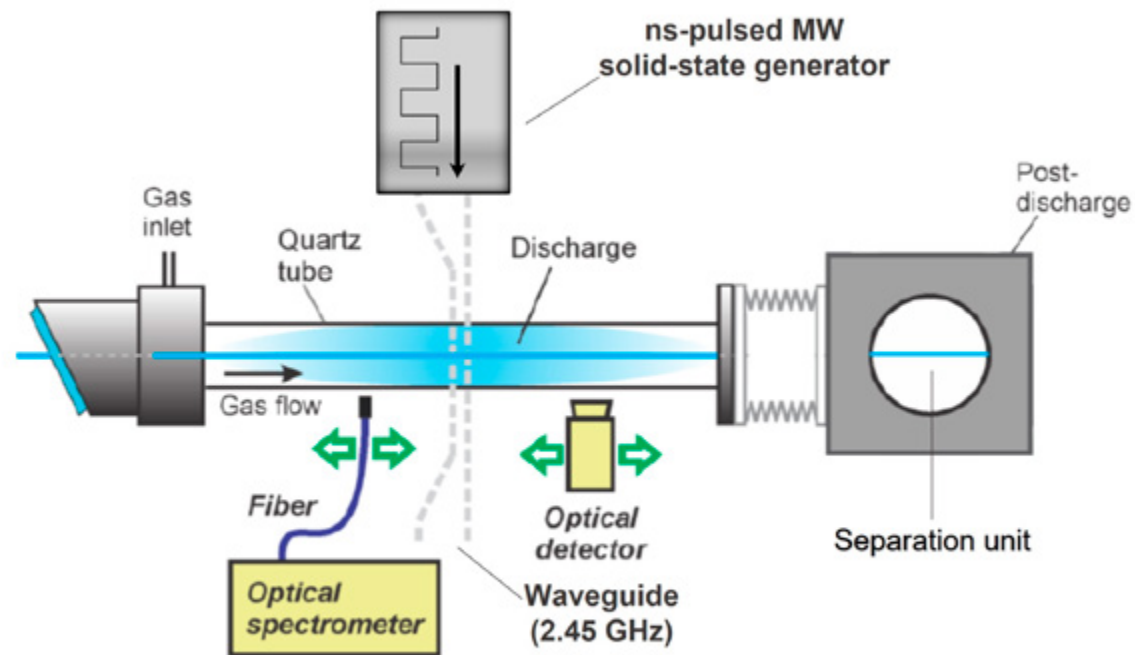
Centre for Nuclear  
Sciences and  
Technologies (C2TN)  
Instituto Superior Técnico,  
University of Lisbon,  
Loures

## Organization

Centre for Nuclear  
Sciences and  
Technologies (C2TN)

This scientific infrastructure is designed to investigate components under high-vacuum at low temperatures and/or high magnetic fields, which contains several cryostats, with up to 50 mm bores, at extreme conditions of low temperature (down to 1.6 K) and high magnetic fields (up to 18 T) under high-vacuum. It is available for both internal and external users.

# Microwave plasma reactor



Lisbon

## Study Field

Physical

## Entity

Campus Tecnológico e Nuclear  
 Instituto Superior Técnico,  
 University of Lisbon,  
 Lisbon

## Organization

Institute for Plasmas  
 and Nuclear Fusion  
 (IPFN)

Located at Campus Tecnológico Nuclear, Instituto Superior Técnico, Lisbon, the currently under development microwave plasma reactor for ISRU studies, namely for the production of  $O_2$  from  $CO_2$ , is available on demand for research activities.

# Ionizing Radiation Facilities Laboratory (IRIS)



Loures



©C2TN

## Study Field

Physical

## Entity

Centre for Nuclear  
Sciences and  
Technologies (C2TN)  
Instituto Superior Técnico,  
University of Lisbon,  
Loures

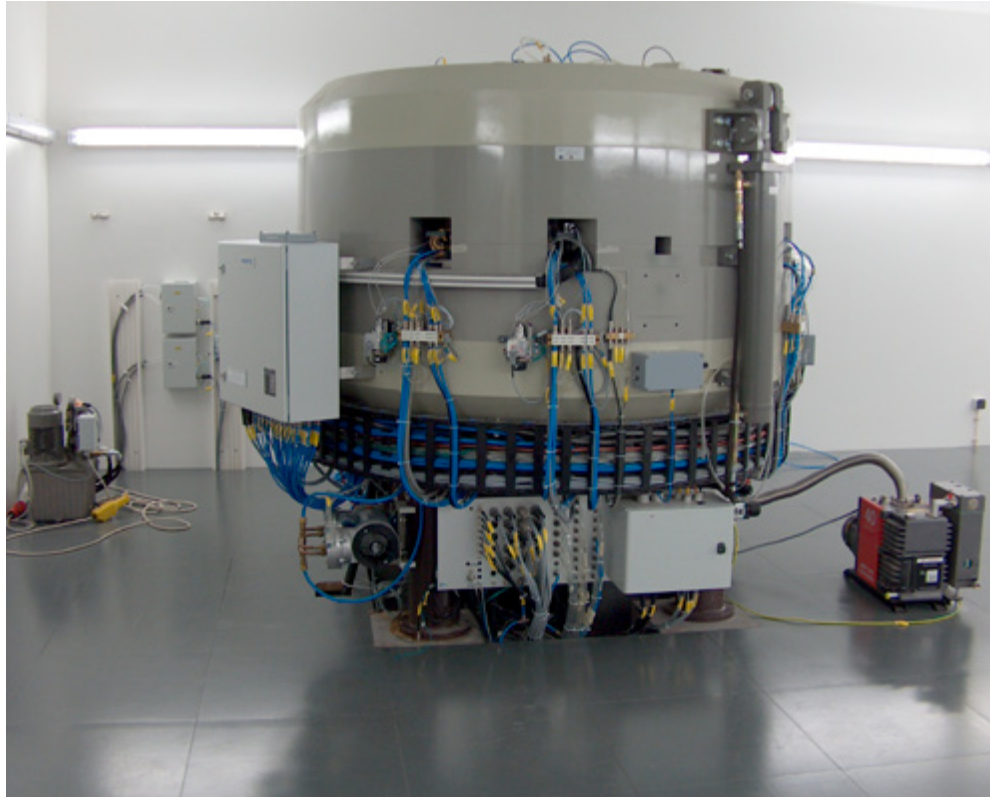
## Organization

Centre for Nuclear  
Sciences and  
Technologies (C2TN)

Ionizing Radiation Facilities Laboratory (IRIS) allows to simulate space radiation conditions and testing of components under ionizing radiation. It was designed to investigate, develop and apply ionizing radiation technologies. The instrument is an experimental Cobalt-60 irradiation facility with a sample rotation device to achieve uniform dose distribution at sample position.

This infrastructure is available for both internal and external users 24h/day, during all year. Currently, it is in the process of licensing.

# Proton Beam Line Irradiation Facility (ICNAS)



Coimbra

## Study Field

Physical

## Entity

Institute of Nuclear  
Sciences Applied to Health  
(ICNAS)  
University of Coimbra,  
Coimbra

## Organization

Institute of Nuclear  
Sciences Applied to Health  
(ICNAS)

The Institute of Nuclear Sciences Applied to Health (ICNAS) of the University of Coimbra hosts a proton beam line irradiation facility based on the proton beam delivered by a cyclotron, model Cyclone 18/9 from the manufacturer IBA. The system was assembled, optimized and calibrated to provide an uniform external proton beam - with maximum energy of 14.77 MeV- that can be used to perform radiobiological in vitro research, simulate space radiation conditions or testing components under proton irradiation radiation, among many other applications.





PORTUGUESE  
SPACE AGENCY