



Space It Up!

Presentation of SPOKE 9

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SPOKE 9: Habitat Space and science

Spoke Leader G. Piotto (UNIPD), co-Leader G. Pratesi (UNIFI)



WP9.2 – Identification and characterization of potential extraterrestrial habitats

WP Leader: INAF-OAA – J.R. Brucato



Activity in Progress (up to M18)

Task 9.2.1 Atmosphere (TL: POLIMI – A. Guardone)

- Performed analyses to study plasma
- Performed analyses on dust, exosphere/atmosphere interactions
- Analyses of atmospheric aerodynamic models and sensors/instruments prototypes.

Task 9.2.2 Lithosphere (TL: UNIFI – O. Vaselli)

- Analyses on geology, geomorphology, mineralogy chemistry, and geophysics of volcanic sites
- Assessment of habitability of terrestrial analogue habitats

Task 9.2.3 Biosphere (TL: UNIBO – B. Cavalazzi)

- Analyses of new techniques for life signature detection
- Analyses of terrestrial analogue sites to predict the evolution of possible future

Task 9.2.4 Exoplanets (TL: UNIPD – Prof. G. Piotto)

- Investigation of bulk structures and atmospheres/exospheres of outer planets and exoplanets, in particular nearby exoplanets (within 5pc) for potential future robotic exploration missions. Study of propulsion technique based on veils and laser for interplanetary travels with micro-chips.

WP9.2 – Identification and characterization of potential extraterrestrial habitats



Activity M18 → to 2028

Task 9.2.1 Atmosphere

- Development of high-fidelity aerodynamic models for the descent phase of a capsule
- Development of sub-models for turbulent dust storm dynamics and impact.
- Atmospheric aerodynamic models and Martian anemometer sensors development.
- Testing of prototypes in terrestrial analogues.

Task 9.2.2 Lithosphere

- Characterization of terrestrial extreme environments.
- Analyses of laboratory data on simulated geochemical processes occurring on Mars and Moon.
- Landscape analyses and mapping of key martian sites

Task 9.2.3 Biosphere

- Studies on biofacies and habitat of terrestrial analogues,
- Assessment of planetary habitability
- Technological solutions for life detection
- Breadboard of instrument for life detection

Task 9.2.4 Exoplanets

- Studies on atmospheres/exospheres of outer planets and exoplanets. Nearby (5pc) exoplanets parameters from Gaia DR4. Exploration of future sub-micro arcsec astrometric missions for exoplanet detection in nearby (few pc) stars. The study of propulsion technique based on sails and laser for interplanetary travels with micro-chips continues, for possible application for flights towards external solar system objects

Expected impact

- Sensors for atmospheric and surface monitoring
- Habitability in extraterrestrial environments assessment
- Extraterrestrial life search in the Solar system and beyond

WP9.3 - Planetary resources: laboratory and in situ analyses, resource mapping

WP Leader: UNIFI – G. Pratesi

Activity in Progress (up to M18)

Task 9.3.1– Astromaterials & Processes (TL: UNIFI – L. Folco)

Mineralogical and geochemical studies on aqueous alteration, magmatic differentiation, impacts processes through the study of martian and lunar meteorites. Research on boninites as analogs for highly reduced bodies (Mercury). Studies of Antarctic micrometeorites for past atmospheric CO₂. Lunar basalts and terrestrial analogs investigated for ISRU and additive manufacturing.

Task 9.3.2– Lunar Water & Site Selection (TL: INAF-IAPS, F. Tosi)

Analysis of Chandrayaan-1/Moon Mineralogy Mapper (M³) data from the Mairan crater region to characterize the distribution, origin, and diurnal variability of surficial OH/H₂O.

Task 9.3.3– Lunar geological mapping and analogue (TL: UNIPD - M. Massironi)

Geological characterization of Etna analogue site of Lunar Maria. Geological mapping, landing site assessment and ISRU potential of pyroclastic deposits on the Moon. Geological characterization of Lofoten analogue site of Lunar Highlands. Evaluation of dust content on ice/dust mixtures as analogue of Martian polar caps and mid latitude glaciers.

Task 9.3.4– 3D Subsurface Modeling (TL: INAF-IAPS A. Frigeri)

3D geological reconstruction and resource-volume estimation were developed using a fully FOSS workflow (QGIS, GRASS GIS, PostGIS, CloudCompare). Validation on a terrestrial analogue (Nerva, Spain) enabled accurate volume estimates, while application to East Tempe Terra (Mars) confirmed transferability to planetary contexts.

WP9.3 - Planetary resources: laboratory and in situ analyses, resource mapping

Activity M18 → to 2028

Task 9.3.1 – Analysis of extraterrestrial materials

Study and classification of extraterrestrial materials, focusing on lunar meteorites. Cataloging of Italian planetological heritage. Study of terrestrial analogs, characterization of regolith and its use ISRU.

Task 9.3.2 – Resources for space settlement

Develop of methods and instrumentation for Lunar surface and subsurface exploration, extraction, and in-situ processing of volatiles and other resources to support long-term human settlement.

Task 9.3.3 – Terrestrial analogs

Investigation of terrestrial analogs (samples and environments) to validate mission methodologies, operational protocols, technologies/instrumentation for exploration systems and resources' supply.

Task 9.3.4 – Resource mapping

Geological mapping and interpretation of geological processes from global to local scales, integrating existing datasets with the development of new portable instruments for in-situ investigations.

Expected impact

Impact on site selection for robotic and human settlements

Impact on site resource availability and properties for ISRU for robotic and human settlements

WP9.4 - Human Life Science & Space Medicine



WP Leader: UNIROMA2 – M. Zago

Activity in Progress (up to M18)

Task 9.4.1 Physiological and biological bases of space adaptations, (TL: UNIPD - M. Narici)

Alterations induced by 21 days HDBR campaign: bed rest without exercise (n=10 subjs) and with exercise (n=10 subjs) consisting of focal muscle vibration (FMV). Functional, morphological and biochemical data have been acquired.

Task 9.4.2 Psychological and neurophysiological aspects. (TL: UNIPD - A. Angrilli)

Analysis of functional brain connectivity in 80 women (young/elderly) under 2 hrs HDBR or sitting conditions. Additional data include sensory deprivation studies and motor control of reaching, arm mechanics, and gravity-related forces

Task 9.4.3 Countermeasures to radiation and altered gravity damage (TL: UNIBO - M. Cerri)

Studies include radioprotection in synthetically torpid mice, transcriptomic analysis of irradiated torpid rats, effects of sumac or polydopamine on Caco-2 cells in simulated microgravity, and ionizing radiation impact on bioengineered human skin models. Pilot study of fission neutron irradiation (TAPIRO) on female mice.

Task 9.4.4 Molecular bases of space adaptation (TL: UNIROMA1 - M. Bizzarri)

Identifies the molecular mechanisms and biomarkers perturbed by space exposure and counteracts them. Strategies, such as anti-oxidants, sirtuins, cytoskeleton, nucleoskeleton and other, are then investigated.

Task 9.4.5 Bioengineering approaches for health monitoring & countermeasures (TL: UNIROMA2 - M. Zago)

Studies investigated cortical responses to immersive spatial navigation, perceptual mechanisms for estimating the duration of vertical movements & shared internal gravity model across visual and vestibular modalities, multilayer intelligent bioprinting, and biofilm formation under controlled gravity, including development of a microfluidic-integrated microscope for altered-gravity bacterial behaviour.

Human Life Science & Space Medicine

WP Leader: UNIROMA2 – M. Zago



Activity M18 → 2028

Task 9.4.1 Physiological and biological bases of space adaptations: Data analysis on alterations induced by 21 days HDBR campaign

Task 9.4.2 Psychological and neurophysiological aspects: Analysis of functional brain connectivity to address gaps in space physiology and gender medicine.

Task 9.4.3 Countermeasures to radiation and altered gravity damage: varied radiation types in torpid models, multi-omics analysis of irradiated rats, mechanistic studies of sumac/polydopamine in Caco-2 cells, translation to 3D human tissue models, and validation of protective strategies under space-relevant conditions.

Task 9.4.4 Molecular bases of space adaptation: Identifies the molecular mechanisms and biomarkers perturbed by space exposure and counteracts them. Strategies, such as anti-oxidants, sirtuins, cytoskeleton, nucleoskeleton and other, are then investigated.

Task 9.4.5 Bioengineering approaches for health monitoring & countermeasures: Future research will focus on: Continuous 24hour monitoring of mental performance/fatigue/emotional state; blink rate as a potential non-invasive marker for crew mental health in long-duration missions. Modulation of multisensory integration with bioengineering approaches and biomarkers, biomarker-based assessment of astronaut wellness, evaluation of real-time defect detection and adaptive control in smart 3D bioprinting and experimental validation in space-relevant conditions, controlled observation of bacterial motility and surface colonization processes under varying gravity levels.

Expected Impact

- Supporting human health and performance during space exploration
- Promoting resilient strategies for crewed space missions

WP9.5 - Study and prototyping of technologies for the human being: WP Leader: UNINA – S. De Pascale

Activity in Progress (up to M18)

Task 9.5.1 – *Production of Fresh Food* (TL: ENEA - Desiderio)

- Assessment of plant tolerance to space-relevant radiation stress (high-LET heavy ions).
- Experimental evidence of hormetic responses and species/genotype-dependent radio-resilience.
- Development of microgreen cultivation protocols using nutrients derived from bioconversion of organic waste (*Hermetia illucens* frass).
- Identification of optimal dilution windows for frass-based fertilizers to enhance early plant growth.

Task 9.5.2 – *Bioregenerative Life Support Systems (BLSSs)* (TL: ENEA - A. Desiderio)

- Validation of closed-loop hydroponic systems using alternative nutrient sources (nitrified urine, biostimulants).
- Experimental analysis of super-elevated CO₂ concentrations (up to 10,000 ppm) on crop physiology, gas exchange, and resource-use efficiency.
- Development of entomological and fungal bioconversion processes for waste recycling in BLSSs.

Task 9.5.3 – *Use of Lunar and Martian Regolith for Plant Cultivation* (TL: UNINA - S. De Pascale)

- Chemical–physical characterization of regolith simulants and processed space organic waste.
- Definition of standardized experimental protocols for regolith amendment.
- Planning of phytotoxicity and biocompatibility bioassays on *Arabidopsis thaliana* using real lunar dust (with UNIFI)
- Smart 3D-printing of regolith-based cultivation structures.

WP9.5 - Study and prototyping of technologies for the human being

Activity M18 → 2028

Task 9.5.1 – Production of Fresh Food

- Scaling up studies on radiation-resilient ideotypes and biofortified crops.
- Integration of high-precision phenotyping for stress-resilient crop selection.
- Optimization of resource-efficient cultivation strategies for fresh food production in space habitats.

Task 9.5.2 – Bioregenerative Life Support Systems (BLSSs)

- Integration of bioconversion processes (humans–insect/fungi–plants) into BLSS loops.
- Refinement of CO₂ management strategies and modeling of matter and energy fluxes.
- Prototype-level validation of closed-loop nutrient and water recycling concepts.

Task 9.5.3 – Lunar and Martian Regolith-Based Cultivation

- Execution of crop bioassays on amended lunar and Martian regolith simulants.
- Execution of and biocompatibility bioassays on *Arabidopsis thaliana* using real lunar dust (with UNIFI).
- Integration and testing of 3D-printed, regolith-based cultivation structures.

Expected Impact

- Strengthened TRL progression of plant-based life-support technologies.
- Robust experimental basis for integrated BLSS architectures for Moon and Mars missions.
- Contribution to sustainable, circular human habitation concepts in space.