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BEYOND UNIVERSEH

European Space University for Earth and Humanity

UNIVERSEH is an alliance of five European universities established to develop a new way of collaboration in the field of Space, within the "European Universities" initiative.
The alliance aims to create new higher education interactive experiences for the university community, teachers and students, and for the benefit of society as a whole. Such initiatives will enable broadminded, informed and conscientious European citizens to capture and create new knowledge and become smart actors of European innovation, valorisation and societal dissemination within the Space sector, from science, engineering, liberal arts to culture.

In Beyond UNIVERSEH, the alliance will develop the research and innovation dimension. By creating a research policy roadmap for 2035 and a vision for 2050 within the space sector, the alliance expects to notably transform the future Space and New Space research landscape, as well to enhance the links between education and research.

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Deliverable n°18-D2.4 Mapping of Space Technology oriented use cases/pilots and end-user driven needs

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UNIVERSEH – European Space University for Earth and Humanity is an alliance of

EUROPEAN UNIVERSITIES Erasmus+

Université Fédérale Toulouse Midi-Pyrénées

AGH

UNIVERSITÉ DU LUXEMBOURG

LULEÅ UNIVERSITY OF TECHNOLOGY

hhu Heinrich Heine Universität Düsseldorf

Dissemination level

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2	28/04/2023	Elizaveta Shashkova	UT/ISAE-Supaero	Input from the partners incorporated
3	28/04/2023	Elizaveta Shashkova	UT/ISAE-Supaero	Final version ready

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1 – Work Package Objectives

The main objective of WP2 is to host all the related activities for generating a complete 2035 Roadmap and 2050 Vision for the development of the research dimension of the European Space University for Earth and Humanity (UNIVERSEH) and propose a set of specific actions for their future implementation within a corresponding timeline. The roadmap must be understandable for a wide non-technical audience, as it will likely be read and reviewed by policymakers and other potentially non-technical stakeholders. To this end, WP2 includes the following objectives:

- Identification of the societal needs including current and future global challenges, that space related research and innovative technologies can solve in a sustainable way.

- Bringing together and establishing an effective dialogue, cooperation and integration among the various constituencies that are currently active in the field of space technologies, as well as with a critical mass of industrial and academic representatives to create an ecosystem that will shape and drive the future innovation and developments in the space sector.

- Evaluation of the enablers to sustain and maximize the implementation of the technologies promoted in the roadmap.

- Elaboration of a UNIVERSEH research roadmap for 2035, that is adoptable, interdisciplinary, collaborative, innovative, enabling to scale excellence by joining forces at a European level.

- Elaboration of a UNIVERSEH Vision for 2050 that will have the EU being a cornerstone of the related developments.

2 – Deliverable Description

The D2.4 is directly linked to the T2.4 which is described as follows:

Task 2.4 will focus on collecting, analysing and presenting the identified relevant applications in the form of use cases and pilot studies from the space sector. Through Task 2.4 Beyond UNIVERSEH will strive to create a direct connection with the European space sector demands and needs to inspire and convince the European industry for a rapid implementation of advanced technologies.

Beyond UNIVERSEH recognizes that the impacts of future space technologies and applications will significantly vary in different industrial space sectors. Thus, Beyond UNIVERSEH will categorize all identified information and organise it into a catalogue. The task will also provide a mapping of a full list of end-user driven requirements and

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needs, integrated with specific space sector demands to provide detailed input to the following tasks of road mapping and vision building in WP2. Task 2.4 will follow an end user driven approach, i.e. this task will be performed in close collaboration with the space industry and related stakeholders and will be evaluated and revised by the UNIVERSEH academic partners, their respective networks and technology providers, before completion of this mapping.

The D2.4 is the description of relevant success stories per space sector in the form of use cases and pilot studies in space academia and industries. Creation of a systematic catalogue of use cases per space sector.

3 – Space research application use cases by partner

3.1 – University of Toulouse (UT)

3.1.1 – ISAE-Supaero

Title Project:	ESA F-Class Comet Interceptor Mission Study
Lead:	J.P. Sánchez, ISAE-SUPAERO, Toulouse, France.
Project Summary:	The European Space Agency Directorate of Science selects its future missions through highly competitive mission calls where scientists across Europe present their missions proposals. In 2018, ESA announced its first Fast-Track (F-Class) mission call, requesting proposals for a small, cheap and quick scientific mission to be launched in 2029. Comet Interceptor mission study took thus place between 2018-2019. It analysed the propulsive costs for a small spacecraft stationed at the Sun-Earth Lagrange L2 Equilibrium point to reach a dynamically new comet. This is a comet that reaches the inner solar system for the first time and, therefore, is still unknown to astronomers. Given this unannounced arrival, there is a need for the spacecraft to be waiting in space and ready to go, as soon as the comet is detected by astronomy surveys. The study computed intercept trajectories to thousands of hypothetic comets. The study demonstrated through statistical analysis that, despite the low propulsion capabilities expected for an F-Class spacecraft, the stored energy at the Sun-Earth L2 point could be wisely used to reach a meaningful population of these comets.
Impact:	The study convinced ESA engineering panel that the mission was feasible. The ambitious scientific objective to visit a yet-to-be-discovered comet convinced also the scientific panel. Comet Interceptor is today being developed by ESA and, once successfully completed, the mission will broaden our understanding of the formation, evolution and emergence of life in our Solar System. Read further in https://www.cosmos.esa.int/web/comet-interceptor.

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Title Project:	Insight - https://www.isae-supaero.fr/en/research/departments/department-of-electronics-optronics-and-signal-processing-deos/sspa-research-team/insight/
Lead:	DEOS/SSPA (David Mimoun, Raphael Garcia, Naomi Murdoch, Nicolas Compaire, Leo Martire, Melanie Drilleau, Alexandre Stott) , ISAE-Supaero, Toulouse, France
Project Summary:	The InSight mission was selected by NASA in August 2012 as part of the DISCOVERY programme. It deployed the first geophysical observatory on Mars on 26 November 2018, to provide scientific knowledge essential to understanding the fundamental processes of the formation of telluric planets and their evolution. To achieve this goal, it is carrying two scientific instruments: the SEIS seismometer and HP3, an instrument for measuring heat flows from the planet's core. SEIS is the most sensitive seismometer in the Solar System. It is currently measuring seismic activity, meteorite impact flux and Phobos tides, as well as helping to characterise the interior structure of Mars, by providing information on the thickness and structure of the crust, the composition and structure of the mantle and the size of the core.It was developed during more than 10 years by the Institut de Physique du Globe de Paris (IPGP) with the support of CNES and CNRS, and a wide range of international partners: IPGP, Swiss Federal Institute of Technology Zurich (ETHZ), Max-Planck Institute Lindau, Imperial College London and Oxford, Jet Propulsion Laboratory and ISAE-SUPAERO. ISAE-SUPAERO has contributed to the InSight mission through the SEIS instrument performance model, the mission performance model, the specification of the scientific software and the design of the concept of operations for the instrument on Mars. ISAE also contribute significantly to the exploitation of scientific data on the structure of the crust, the internal structure of the planet or the study of dust devils.
Impact:	First of all, understanding the sources of noise on the Mars surface (wind, atmospheric pressure, magnetic field and temperature variations) and their impact on the seismometer SEIS contributed to the exploitation of the data it provided. The analysis of the data allowed to better understand the internal structure of Mars, its formation as well as the proprieties of the Martian regolith and the whirlwind of dust on its surface.

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3.1.2 – Toulouse Business School Education (TBS Education)

Title Project	Developing Organizational Ambidexterity in a Space Organization
Lead :	TBS Education and a Space organization (confidential)
Project Summary	TBS Education is working alongside a space organization to develop disruptive projects and innovations by anchoring organizational ambidexterity. At the organization level, developing ambidexterity will promote innovation culture in the space organization and will contribute the organization to cope with the many changes occurring the space industry, referred to as New Space (including new entrants, new policies, new technologies). At individual level developing organizational ambidexterity is perceived as a strategic development axis able to foster the working force well-being, enhance competencies development and finally act as a career accelerator. For 4 years, 42 interviews has been leaded by TBS Education within the collaboration of several actors of the space organization (projects leaders, business units directors and even punctual participants) with diverse profiles and competencies (electronic, software, satellites construction, etc.) working on various thematic such as Earth observation, Telecoms and Navigation.
Impact	So far, the data collection phase has been done and TBS Education is working very closely with the Space organization project leaders. The analysis phase is ongoing and 3 teachers-researchers from TBS Education are collaborating. The working analysis will be published and shared to develop good practices on this topic. Long-term reflection and survey upon ambidexterity aims to adapt employees working environment to New Space disruptions and enable them to develop their efficiency and competencies.

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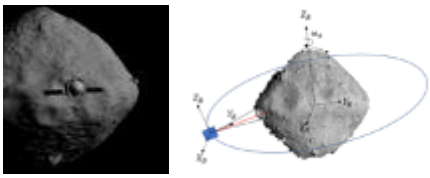
3.2 – Luleå University of Technology (LTU)

Title Project:	RIT 2021: NRFP-4: Visual Navigation around a Small Celestial Body
Lead:	Prof. George Nikolakopoulos, Luleå University of Technology, Luleå, Sweden
Project Summary:	NRFP-4 project is a collaborative initiative with ***OHB Sweden***, under RIT 2021, as a co-financed EU project. NRFP-4 established an autonomous visual navigation framework around small celestial objects. Exploring small celestial objects like asteroids and comets is of great importance to the space community, as they contain evidence about the evolution of the solar system and the origins of life. The scientific interest in bringing back samples from near-earth objects and a global interest in protecting Planet Earth from future collisions with celestial objects, drives the high demand for asteroid exploration missions. In such ambitious missions, precise and autonomous space navigation is critical. The NRFP-4 project proposed a robust navigation architecture that enables precise onboard autonomous visual navigation around a small celestial body (illustrated in Figure 1), using a Vision-LiDAR fusion-based Simultaneous Localization and Mapping (SLAM) algorithm.  Figure 1. A Vision-LiDAR fusion-based SLAM algorithm for autonomous navigation around an Asteroid. The state-of-art ORB-SLAM algorithm is used for processing consecutive image frames for deriving the spacecraft's pose. To overcome the deviations in the pose from ORB-SLAM algorithm (which render it unreliable), the project combined the image features with a projected LiDAR point cloud to determine the spacecraft's pose. To eliminate vision component's excessive reliance on good illumination, the solution incorporated a model-based propagator (using IMU, LiDAR, and model predictions) to provide pseudo-sensor measurements. This approach ensures that the algorithm's performance is resilient to varying illumination conditions and measurement noise. A representative result of the project can be viewed at https://youtu.be/GJcTFMqzpzI.
Impact:	The outcome of the NRFP-4 project, which is a framework for robust vision-based autonomous navigation, has immense utility in the future asteroid missions, due to its novel multi-sensor fusion approach, which enables operation irrespective of the illumination conditions around an asteroid. For the overall implementation, a virtual reality (VR) testbed was created in the physics-based Gazebo simulation software. This demonstrated the usefulness of Gazebo software, which is predominantly used in Robotics, for simulations in Space research. The designed VR testbed can be further used to develop and evaluate any other Guidance, Navigation and Control algorithm, for the development and validation of missions such as planetary landings, autonomous rendezvous and docking, and in-orbit robotic servicing.

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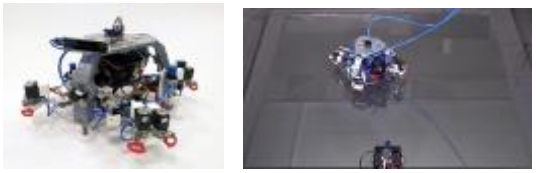
	More information can be found at: **https://ritspace.se/ai-to-navigate-space-exploration-in-new-innovation-partnership/**

Title Project:	Slider: A floating platform. A space technology-oriented pilot project
Lead:	Prof. George Nikolakopoulos, Luleå University of Technology, Luleå, Sweden
Project Summary:	The development and validation of satellite guidance, navigation, and control (GNC) algorithms is performed on earth on hardware-in-the-loop spacecraft test-bed facilities, in environments that emulate space-like conditions. Various government organizations and university laboratories across the globe have such indigenously built testbed facilities. As no such testbeds are commercially available, there is a growing need for low-cost and 3D printable designs for: 1) integration into academic GNC courses to provide hand-on student experience and 2) for emerging startups to test their payloads and algorithms. The Slider (shown in Fig. 1) is a floating platform integrated with actuator units and sensors for visual navigation, that is fully designed and manufactured by the Robotics and Artificial Intelligence (RAI) group at Luleå University of Technology (LTU). The research activities at RAI in space robotics and autonomy are supported by multiple Sliders, which are used to emulate the orbital motion of spacecrafts.  Fig. 1: The Slider platform, a hardware-in-loop spacecraft test-bed facility. The Slider platform is supported by three air bearings, which release compressed air to form an air cushion, thus allowing Slider to levitate over a smooth surface. A detailed design along with the mathematical model describing the platform's dynamic motion has been published and the entire design, including 3D printable CAD models have been open-sourced. Several experimental demonstrations have been performed to showcase the Slider's capabilities and illustrate its operation, some of which can be seen in the following videos. 1)https://www.youtube.com/watch?v=nJjMiHpQhhA 2)https://www.youtube.com/watch?v=x2VSadbrBvk 3)https://www.youtube.com/watch?v=v5b94caNKAs 4)https://www.youtube.com/watch?v=vvGkSl2ArP4
Impact:	Research Impact: Floating platforms, like the Slider, allow for testing of spacecraft GNC algorithms on ground. So far, Slider has been used to develop and validate algorithms for safe autonomous docking, trajectory tracking with variable payloads etc. For emerging startups, which are

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	aiming to validate their technologies on testbeds emulating operations in space, platforms like the Slider are extremely beneficial. The Robotics and AI group at LTU has been approached by several emerging startups, to host their sensors and algorithms onboard the Slider Platform, for testing and performance evaluation. Pedagogical impact: The Slider platform has been integrated into the Spacecraft Guidance and Navigation course at LTU. The platform is providing hands-on experimental experience to the students. The detailed CAD designs of the Slider platform have been open sourced and most of the parts can be easily 3D printed and assembled.

Project Title	Createrity Space: Circular Economy for Reuse and Recycle of Spacecraft Materials
Lead	Anna Öhrwall Rönnbäck and René Laufer, Luleå University of Technology, Luleå and Kiruna, Sweden
Project Summary	The need for material circularity and sustainability is not limited to human activities on Earth and in fact, has broad implications for the utilization of outer space. With the increased digitalization, global location and observation needs, and connectivity demands for Earth applications, an ever-growing number of spacecrafts being launched into an already "crowded" orbital space at the fast-growing risk of collisions. Sustainability, stewardship, and circularity have been identified as key concepts and enablers for the save and long-term utilization of outer space. However, as research projects related to space sustainability, recycling of spacecraft materials, and space debris mitigation gain traction, a mutual understanding of definitions and concepts is missing and the prospects and viability of circularity in space are unclear. This research attempts to fill this gap with an investigation into the possibilities to re-use spacecraft materials as an alternative to its complete disposal. A review of circularity and sustainability definitions is conducted, and to make an initial effort to examine and map requirements for re-manufacturing, refurbishment, and the re-use of spacecraft materials. A literature review is conducted to identify fundamental concepts to enable circularity. This research reviews best practices and approaches in areas like aviation, electronics, and car manufacturing to thoroughly examine similarities and to create a mapping for the space sector. Following this cross-industry approach, the research surveys academic and industrial topics like spacecraft and satellite mission design, business models and product innovation, and entrepreneurship and space ecosystems to find common patterns within sectors and activities. Consideration of a long-term view and the sustainable use of resources are among the major challenges for society, industry, and academia. Transitioning from a linear to a circular economy is seen as a vital part and key enabler for sustainability. Nevertheless, the application of either concept depends on industry sector needs, technological feasibility, economic viability, and industry regulation. With humanity getting ready to explore and possibly settle in our solar system beyond Earth within the next century, we suggest a broader view and the need for new definitions of sustainability. The aim is to create a common understanding and with this, to advance the space economy by reusing spacecraft materials and recycle the non-reusable parts.

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Impact:	Of course, the development of any technology doesn't make it beneficial by itself. If reuse of spacecraft materials is possible form a technology point of view, the space industry still must make it financially viable. Now, sustainability in space, regarding laws and regulations has three main topics under investigation: - Equality regarding the countries (or entities) entering space exploration and the country pioneer in space exploration: should they be allowed to do the same mistake than their predecessors? - Seeing space as a limited environment: the space used, around Earth, is a finite resource. - Extension of the idea of reuse/recycle/repurpose and manufacturing in space. This research attempts to contribute to all three but has its focus in the reuse and circularity topic. There are a few laws related to repurposing of space debris, with the most important one that space objects, including space debris, are legally under the jurisdiction and laws of the launching country. There is no salvage law in space as in the ocean. A suitable environment for the implementation of circularity in space and for reuse of spacecraft materials is closely related of the law issues of space debris. For more than sixty years, spacecrafts were left in space without any concern on the consequences due to the lack of more strict regulations. It can be compared to the carbon-dioxide emission on Earth before the application of stricter laws and taxes the industries have no direct interests to diminish their emissions. Therefore, one can imagine if the government implement a tax on the number of space debris "emitted" by a space actor or on the launch; it might force the space actors to rethink their spacecraft end-of-life and to investigate a circular mission model. Of course, the capability to reuse a spacecraft presents a geopolitical risk too, it could be militarized to attack a satellite and by extension its owner. Therefore, regulations might evolve within a circular space economy.

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Project Title	KvarkenSat: The First Finnish-Swedish Collaborative Nano Satellite
Lead	Heidi Kuusniemi, University of Vaasa, Vaasa, Finland, René Laufer, Luleå University of Technology, Kiruna, Sweden
Project Summary	Kvarken Space Centre is a project funded by the European Regional Development Fund to implement a long lasting regional economic develop- ment structure for space-based business and inno- vation. Kvarken is a region across the Baltic sea that shares common cultural and economical rela- tionships between Sweden and Finland. The primary objective of the planned centre is to support regional businesses to develop opportunities within the “new space economy” and commercialise existing space-based data. The centre will share knowledge and implement demonstration projects to bring the regional businesses to the level needed to independently manage their own space business activities. One of the aforementioned demonstration projects includes the development and operation of a satellite, called KvarkenSat. Ten partners comprise the space centre, of whom six are involved in the develop- ment of KvarkenSat: Luleå University of Technology, Aalto University, University of Vaasa, Swedish Institute of Space Physics, Swedish University of Agricultural Sciences and Novia UAS. a) Technical Objectives - To provide hyperspectral images of the Kvarken Region and other areas of interest for monitoring, analysis and/or modelling of land and sea features. - To perform the in-orbit demonstration of a university-built AIS receiver for sea vessel tracking. - To provide unprocessed satellite navigation data on multiple frequencies for the later characterization of such signals. - To demonstrate and characterise the in-orbit performance of an array of water-based thrusters for spacecraft maneuvering. b) Educational Objectives - To advance the competence of the development team and involved parties to design and operate nanosatellites and ground stations. - To provide hands-on and project experience for university students. c) Outreach Objectives - To spread awareness and display the capabilities of the Kvarken Space Center and its actors, aim- ing to boost space-based business and innovation in the Kvarken region. - To provide local citizens the experience of ob- serving the design, implementation and opera- tions of a CubeSat mission closely connected to the Kvarken region. KvarkenSat will comply with the CubeSat standard, a satellite in the nano-size class that consists of one or more 10 cm × 10 cm × 10 cm cubes. Its benefits are modularity, some degree of standardisation, agility and low cost. Through the development of KvarkenSat, the center plans to demonstrate the mission end-to-end processes while sharing progress systematically with industry and organization members.

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Impact:	Kvarken Space Centre is a project conducted by a consortium of Finnish and Swedish academic institutions aiming to enhance the economic activities of the Kvarken region shared by the two countries, by improving the regional competence in space technology. In this framework, the consortium is developing KvarkenSat, a first 2U CubeSat with the goal of exhibiting the regional capabilities in satellite development via performing science and in-orbit demonstration of Finnish payloads. Since the main areas of interest are forestry and sea transportation, the 2U CubeSat will integrate a multispectral camera for forest health and seawater quality analysis and an automatic identification system (AIS) receiver for sea vessel tracking. In addition, the spacecraft will perform the in-orbit demonstration of a miniature water-based resistojet thruster system. KvarkenSat's last payload will comprise a GNSS receiver that will extract raw data in order to conduct precise point positioning (PPP) algorithm research. The development of KvarkenSat is currently in phase D. The launch process for the CubeSat is envisioned to be accomplished at the Esrange Space Center in Kiruna, Sweden through a flight opportunity awarded by German Aerospace Center (DLR) on one of the demonstration flights for new micro launcher space transportation vehicles and may be one of the first missions to gain access to space from northern Sweden.

3.3 – AGH University of Science and Technology (AGH)

Title Project:	AlignSAR
Lead:	AGH, Krokow, Poland Partners : University of Twente, The Netherlands (Lead partner), University of Leeds, United Kingdom, AGH University of Science and Technology, Poland, and RHEA Group, Italy
Project Summary:	The project aims to provide FAIR-guided open datasets and tools designed for SAR applications, ensuring interoperability and consistency with existing and upcoming initiatives and technologies. The project facilitates a wider exploitation of SAR data and its integration and combination with other datasets. The project aims to achieve the following objectives: · Define a procedure for creating SAR benchmark datasets for machine learning applications. · Develop a reference, quality-controlled, documented, open benchmark datasets of SAR spatial and temporal signatures of complex real-world targets with high diversity to serve a wide range of applications with societal relevance. The database will respect FAIR (Findable, Accessible, Interoperable, Reproducible) and Open Science principles. · Create the database considering both open and closed SAR missions (including at minimum Sentinel-1), maximizing the geographical and temporal coverage, and integrating and aligning multi-SAR images and other geodetic measurements in time and space. · Define a specification of the signatures and their associated descriptors so that they can be easily indexed, programmatically searched, and retrieved.

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	· Develop an open-source software library with associated documentation to create, describe, test, validate, and publish SAR signatures, and expand the database. · Demonstrate, test, and validate the Open SAR Library (database and open-source software) on at least two use cases for machine learning applications. · Ensure long-term availability of the database and open-source library, potentially through integration with other relevant open platforms and tools. The project is funded from the European Space Agency (ESA) in response to the ITT ESA AO/1-11394/22/I-DT. It kicked off in February 2023.

Title Project:	LOOP - Landing Once on Phobos
Lead:	AGH, Krakow, Poland
Project Summary:	The goal of the project is to launch the first lander to a Mars satellite - Phobos. It is one of the two moons of the planet. Its area is over 6,000. km. The task is difficult due to the conditions prevailing on this Martian moon, which have not been studied in detail. Scientists assume that the gravitational acceleration on Phobos is over a thousand times smaller than on Earth, and the temperature ranges from minus 4 to minus 112 degrees Celsius. Another problem is limited knowledge about the soil of Phobos (called regolith). When landing, the moment of contact of the lander's feet with the surface of the moon will be crucial. According to the AGH UST release, determining various scenarios of the Phobos surface structure is one of the tasks of the research team from the Faculty of Mining and Geoengineering of the AGH UST in Kraków. In addition to finding a material with a similar composition to the soil on Phobos, the AGH UST research team will also develop a mathematical model of the contact of the lander's feet with the Phobos' surface. Due to the very low gravitational acceleration, it is important that the lander rests on the ground on the first attempt instead of bouncing off the surface. The subjects of experimental laboratory work, in addition to reconstructing the conditions on Phobos, will also include the study of the reaction of various soil types to the load of the lander's foot. The project was funded by the ESA Contract No. 4000122600/17/NL/CBi

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Title Project:	Swarm4Anom – Investigation of the linkage between ionospheric plasma night-time density enhancements and magnetic field variability
Lead:	AGH, Krakow, Poland
Project Summary:	The Swarm for Anomalies - Swarm4Anom is a project led by Space Research Centre PAS (Polish Academy of Sciences) in cooperation with a start-up OBSEE The Swarm for Anomalies project, in brief named as Swarm4Anom, is focused on the linkages between ionosperic plasma night time density enhancements and magnetic field variability. Ionisation reversed diurnal cycle is one of distinctive features of the Earth's ionosphere, which is characterised by higher values of ionospheric plasma density registered in the night-time than in the daytime. Two well-known examples of this phenomenon are the Weddell Sea Anomaly (WSA) and the mid-latitude nighttime summer anomaly (MSNA). The WSA is a mid-latitude F region ionosphere phenomena taking place over the regions west of the Antarctic Peninsula. Though the WSA was discovered more than 60 years ago, still its generation mechanism is not fully understood and its modelling remains a challenge. Initial discovery of the WSA relied on measurements from the ground network of ionosondes. Satellite observations revealed that peculiar feature of the ionosphere is not limited to the southern hemisphere only. Similar behavior is also present in the northern hemisphere. In situ registrations of electron density from the Langmuir probe on board three Swarm satellites are used to study spatial and temporal evolution of night-time plasma density enhancements (NPDEs). The study introduces the normalised density difference index I_NDD (Normalized Density Difference Index) in order to provide global estimates of the phenomenon. I_NDD is provided as a higher level product derived from Swarm data. The project was funded by the ESA, Contract No. 4000112769/14/NL/FF/gp

3.4 – Heinrich Heine University of Düsseldorf (HHU)

No space research technological use-case has been identified in HHU.

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