SPACE RESOURCES WEEK 2022

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SPACE RESOURCES WEEK 2022: OUTCOMES AND LESSONS LEARNT

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All sessions of the Space Resources Week 2022 are available on the **ESRIC YouTube channel**

Introduction

In May 2022, the European and international Space Resources community was invited to join the Space Resources Week. This event, organised by the European Space Resources Innovation Centre (ESRIC), followed the successful 2019 and 2021 events and the collaboration of the Luxembourg Space Agency (LSA), the European Space Agency (ESA), and the Luxembourg Institute for Science and Technology (LIST). The 2022 Space Resources Week started with one and half days of professional courses delivered by the International Space University (ISU), the Colorado School of Mines, ESRIC, ESA and LSA which provide a broad overview of the space resources field to professionals of all experiences and sectors.

The courses were followed by two and half days of workshop, where 300 people attended on-site, in Luxembourg, and close to 700 people joined online the hybrid event. 103 speakers were invited to present their work on stage, and 26 poster presenters completed the event, covering a wide spectrum of expertise and interest, from programmatic, commercial, law, banking, research, and technology, focusing on the Moon, Mars, and asteroids. The overall focus of the 2022 event was on sustainability.

Mission updates from Hayabusa 2, the Martian Moons eXploration (MMX), PSYCHE, and HERA showcased the next steps towards understanding asteroids and their resources. Oxygen extraction results from Mars' atmosphere with MOXIE were also shown at the workshop. As for lunar missions, development updates from the European payloads PROSPECT and ISRU-DM were presented to the audience. Another workshop session focused on the field's latest research activity, presenting new means to beneficiate regolith, extract resources, and manufacture structures on the Moon and Mars. Technology was also showcased with demonstrators of regolith sintering, gas processing, and robotic arms and power systems (e.g., fuel cells) enabling space resources processes.

In this paper, more details are given on the key sessions of the workshop, including the status and agency perspective, circular economy for commercial sustainability, law and regulations, financing, simulants and future pilot plants.

Sustainability was the overall focus of the 2022 event

Space Resources: status and agency perspectives

Heads and officials of space agencies presented their visions for space resources and exploration. In his opening speech, the Luxembourg Minister of the Economy Franz Fayot recalled the rapid progress of space resources utilization worldwide and the key developments implemented in the frame of the SpaceResources.lu initiative since 2016. It was emphasised that circularity of space resources is key for the sustainability of space operations but also for stimulating a change in Earth activities, towards solving challenges such as climate change and loss of biodiversity.

Furthermore, the appointment of Dr. Kathryn Hadler as a new director of ESRIC reinforces the position of Luxembourg in space resources utilization as a European hub in the field. ESRIC connects research, knowledge management, business, and the community around the field of space resources.

Once viewed with hesitation, Space Resources is now on the agenda of many space agencies worldwide, and the pioneering effort of Luxembourg was stressed by ESA Director General Josef Aschbacher: space is now part of the economic zone, with space resources playing a key role in a near future.

David Parker, ESA Director of Human and Robotic Exploration, presented ESA exploration ambitions in Low Earth Orbit, and on the Moon and Mars.

ESA currently focuses on lunar resources: prospecting ice and volatiles, developing oxygen and metal extraction technology, targeting the delivery of a pilot plant to be delivered by the mid-2030s. However, a big difference still remains in private and public investments in space in Europe compared to the rest of the world. European stakeholders have a role to play to increase the European engagement in the space endeavour.

As for space resources outside Europe, the NASA Artemis programme considers ISRU as essential for exploration of the Moon and future destinations, making the missions safer and more sustainable. As explained by NASA associate administrator Robert Cabana as well as Jerry Sanders, lead for ISRU at NASA, NASA activities cover the whole space resources value chain.

A full end-to-end demonstration at the lunar surface is considered essential before considering the utilisation of space resources for mission-critical applications. The president of JAXA, Hiroshi Yamakawa, emphasized Japan's growing interest in the field, pointing out the utilisation of space resources will first depend on the knowledge gained from early exploration missions of the surface of planetary bodies.

The Lunar Exploration mission (LUPEX) that Japan prepares together with India will look at the availability of water-ice on the Moon.

Circular economy for commercial sustainability

This session investigated how to balance the environmental, economic, operational, and technological impacts that ensure the availability of resources for future generations and the long-term success of space resources companies.

The first part of the session focused on incubation programmes, collaboration opportunities and standardisation: all critical elements to building successful space resources companies.

ESRIC's Start-Up Support Programme (SSP) is the first incubation programme worldwide dedicated completely to space resource utilization. The five selected start-ups for phase 1 were presented: they target 3D printing technologies for manufacturing, designing and constructing robotic transportation and exploration systems, and orbit recycling technologies.

ESA also acknowledged the complex and long path for space start-ups to be economically sustainable and develop their business application programmes. The ESA Space Solutions Programme guides these companies from concept design and prototyping and, finally, through the development and validation processes calls for feasibility studies and demonstration projects.

The space resources value chain is long and complex; therefore, all stakeholders would benefit from establishing strong, long-term collaborations. In this context, Euro2Moon was created as an open association of European companies and organisations aiming to position the European industry as a leader in creating the cis-lunar economy.

International cooperation is also key to creating standards to ensure the best practices preventing the space resources sector from repeating the mistakes that terrestrial mining companies did, including harmful environmental impacts. Terrestrial quantitative impact assessment for products and services is done in the framework of the ISO 14040 series standards on life cycle assessment (LCA). It was proposed to use LCA or similar methods to assess space activities' impacts to identify areas of special protection.

To reduce their harmful environmental impact, terrestrial mining industries are looking at circularity to design products and services reducing minimum waste and pollution. This approach is of special interest in the space resources field when turning waste into useful valued products would reduce the impact of the activity while generating commercial profits. The first application could be to reuse space debris, as several speakers presented during the space-to-space session: in-orbit space debris could be recycled, reducing the orbital waste and collision risks.

According to some speakers, lunar water resources are finite, and their use for propellant should be minimised as that would deplete the reserves quickly. Water has to remain available on the Moon for future generations of lunar settlers that may use it for other purposes. To supply LOx, the extraction of oxygen from lunar minerals and the design of transportation architectures that take advantage of astrodynamics could reduce the harmful environmental impact while significantly increasing commercial returns.

Space resource utilization will be impossible without robotic explorers and miners, able to navigate and identify materials of interest through edge-AI telerobotics and perform joint operations using multi-robotic architectures. However, until a market for space resources is established, robotic space companies require more immediate customers on Earth while developing and testing their technologies and novel operation concepts. This allows the company to have immediate revenue while disrupting mining on Earth. Besides robotics, other technologies being developed for lunar resources can be applied to Earth. ESA is currently investigating space-based solar power (SBSP) to supply energy to lunar surface activities wirelessly. Such technology also has a terrestrial application that can help alleviate the energy and climate problems affecting our planet.

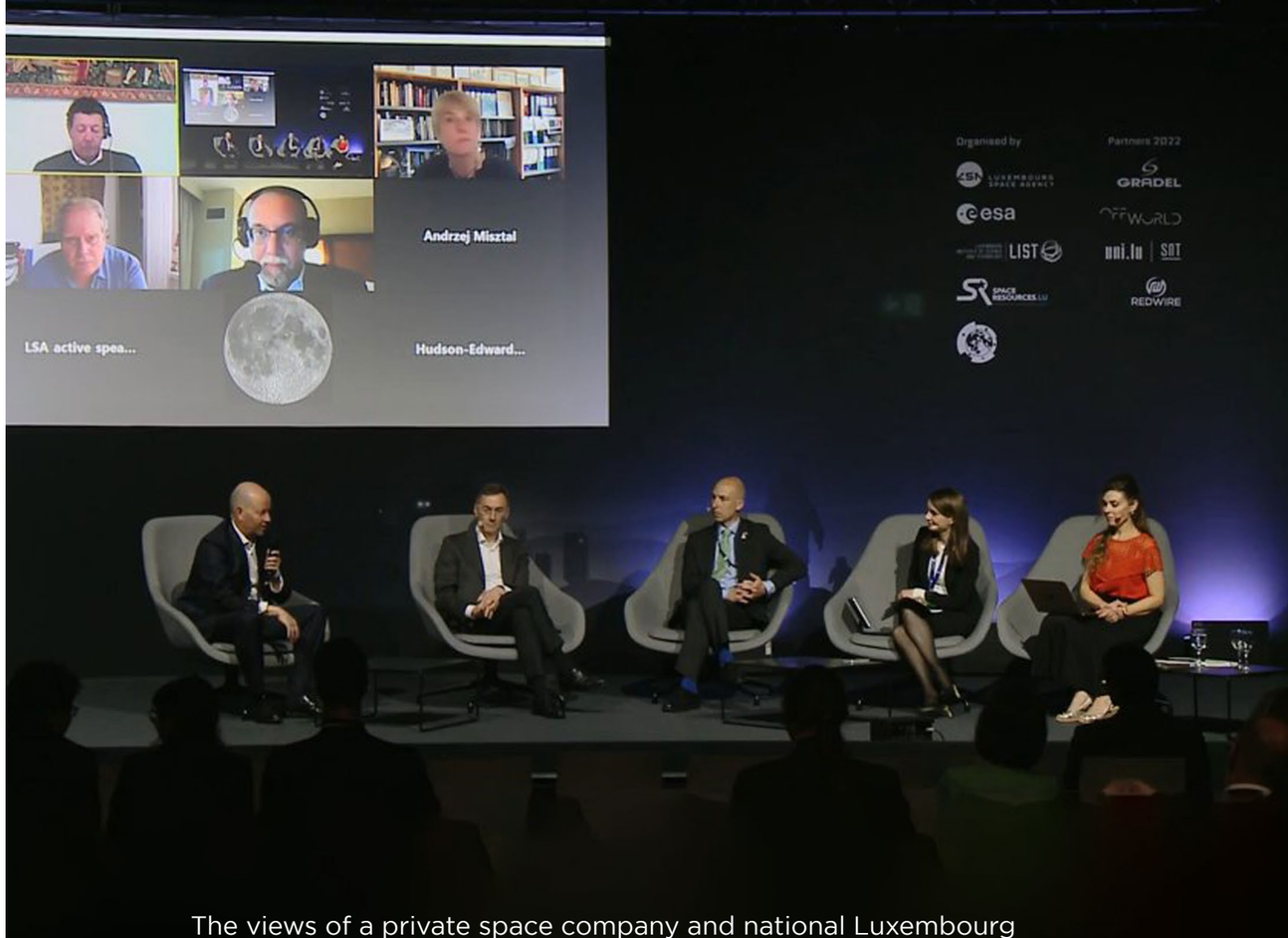
Law and regulations

The legal and regulatory session “Preserving Space Environment - Harmful impact considerations in the international framework: Avoidance, Mitigation, Monitoring, and Remediation” focused on the ways to preserve the space environment and the management of the harmful impacts. The topic of the session was selected for several reasons. The space resources activities will pose a significant risk to space and Earth’s environment and generate hazards; therefore, they should require care, standards, and proper due diligence. There is a need for national legal, and international frameworks to regulate these activities involving private actors to promote sustainable and responsible activities. Questions such as priority rights, environmental issues, dispute resolution – and many others – have to be addressed internationally.

The session gathered recognised speakers from academia, NGOs, international organisations, space agencies, terrestrial mining, and private and public sectors. Presentations from speakers were followed by a panel discussion debating how to navigate stakeholders’ needs, opportunities, and challenges considering the environmental issues in the international space resource activities framework.

The session started by presenting harmful impact-related provisions of Building Blocks for the Development of an International Framework on Space Resource Activities produced by the Hague International Space Resources Governance Working Group. The Building Blocks is a valuable contribution to the reflection about a future framework for space resources activities in the international fora, such as the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). Harmful impacts on the international space treaties, the responsibility and liability regime, and recent development at COPUOS were also presented during the session.

Two speakers from COSPAR and UNOOSA looked into the sustainability of scientific investigations in outer space and developing the COSPAR planetary protection policy. The speakers talked about avoiding interference between operators and how NASA addresses these aspects in their programmes, and in the Artemis Accords, which attracted 19 national signatories from nearly every region of the world.



The views of a private space company and national Luxembourg position were outlined.

The speakers recommended learning from terrestrial mining. Considering the concept of Social License to Operate (SLO) from the terrestrial mining sector for the space resources activities would be pertinent. SLO generally defines the efforts and activities an extractive company takes to build and maintain goodwill or social capital with the communities close to where they operate.

Financing: Make resources and the Moon bankable

As part of the second day's activities, ESA organised a panel on the subject "How to make the Moon Bankable"? The panel counted the participation of experts in infrastructure development, private finance, and resource trading. The panel highlighted how important it is to include stakeholders outside the technology domain early: they are the ones that will finance and trade Space Resources beyond the initial exploratory phases and need to guide developments during the whole process.

The panel profusely discussed the role of effective trading mechanisms for Space Resources to succeed. Existing marketplaces will need new ones specifically targeting ISRU. This will require large investments in infrastructure for extracting and moving resources and deep-space-to-deep-space and deep-space-to-Earth communications, which are essential for trading.

Such endeavour will require complex financing and cross-sectorial awareness. ESA's experience with the ESA Investor Forum is a good starting point to approach private investment and educate stakeholders across sectors. The Investor Forum will need to shift its activities. Since there will be a role for venture capital, Space Resources will also require financing of big infrastructure.

Simulants supporting research

Lunar regolith simulants, or other analogue sample materials, are critical for space resource research activities. Efforts are ongoing in Europe and the US to characterise, standardise, and qualify such materials and better inform the research community on the appropriate utilisation of these materials in research. K. Manick (ESA) from the ESA Sample Analogue Curation Facility (SACF) presented the European perspective, and K. Stockstill-Cahill (John Hopkins Applied Physics Laboratory) presented the recent work of the Lunar Surface Innovation Initiative (LSII) Simulant Working Group in the US.

K. Manick (ESA) outlined the capabilities and future direction of the ESA Sample Analogue Curation Facility (SACF). The SACF aims to be a European focal point for the curation and characterisation of analogue samples and to provide expert support on analogue samples for R&D projects in Europe. Recommissioning post-Covid is underway, and steady-state operation should be reached in 2023. The SACF conducted an Analogue Sample Users Survey in March 2022 and identified many challenges and user needs in the European simulant/analogue sample user community. The SACF intends to address health and safety recommendations, characterisation and validation, and information collation and sharing needs. Challenges relating to simulant accessibility within Europe, research into simulant production, and batch quality control require a wider network. A European Simulant Supplier Workshop in April 2022 addressed these challenges. Along with identifying the role of ESA and the SACF in creating a supply network map, identifying supply chain gaps, and fostering community initiatives, a key outcome of the workshop was identifying the long-term strategic goal of independent simulant supply in Europe, where simulant imports can be seen as an interim measure to meet demand.

K. Stockstill-Cahill leads the LSII Simulant Working Group, which was established to provide an independent evaluation of lunar simulants according to various characteristics and inform simulant selection for research activities. Since 2020 this group has published an annual Lunar Simulant Assessment that characterises and evaluates the currently available simulants in the US.

Typically, these simulants approximate many aspects of real lunar material but miss components unique to real lunar material, such as agglutinates, nanophase iron, and amorphous mineral rims.

K. Stockstill-Cahill presented the most recent 2021 assessment results and highlighted some key conclusions: the evaluation and utility of a simulant are specific to its application, regolith simulants and real regolith do not necessarily behave the same way on Earth as they would on the Moon, and Lunar simulants from current providers meet the needs of most users, however, for advanced testing (high-TRL) it is recommended to compare results using simulants with and without pseudo-agglutinates.

Pilot plant

The roundtable on the Lunar Pilot Plant has featured panellists with varied backgrounds, with representation from ESA and NASA (B. Hufenbach and J. Sanders, respectively), from research institutions such as the European Space Resources Innovation Centre (K. Hadler), Industry (J. Vrublevskis from Thales Alenia Space and B.Baratte from Airliquide) as well as the perspective of the ISECG (J. Alves chair of the ISECG ISRU Gap Analysis workgroup). After an introduction to ESA's vision of the Pilot Plant, which is to prepare for deployment and operation of oxygen and metal-producing Lunar Pilot Plant in the mid-2030s, it was presented and highlighted how the work has already started in ESA with ground-based research and the ISRU Demonstration Mission payload study (ISRU-DM). The next concrete steps are the feasibility study for the design and build of a Terrestrial Pilot Plant in ESRIC, and a Concurrent Design Facility Study at ESA for the Lunar Pilot Plant in the fall of 2022.

The Pilot Plant is a very important feature in the ISECG studies and is confirmed to be a cornerstone of the Artemis program for humankind's sustainable return to the Moon's surface. In particular, for the Terrestrial Pilot Plant, there is a strong emphasis on engaging with the community in the definition of such Pilot Plant, and to create a platform where the community can contribute to the build-up and eventually use the platform to test new technologies and new disruptive ideas.

The panellists concurred on many occasions that this would represent a unique opportunity for collaborations among industry players and agencies. However, this is not without issues and challenges.

Themes that have been highlighted are:

- National regulations that are hindering the exchange of knowledge and know-how
- The evolving outlook on the legal framework that will be required to ensure sustainable utilisation of in-situ resources, and
- Challenges with the current political and economic international landscape.

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