

LUXEMBOURG SPACERESOURCES.LU INITIATIVE

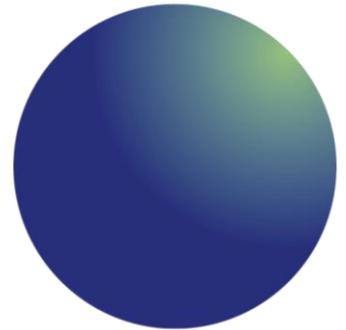
The Luxembourg Perspective on ISRU and the Development of a Commercial Space Ecosystem

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Since 2016, Luxembourg has implemented a comprehensive strategy to realize its vision of space resources utilization



Luxembourg aims to contribute to the peaceful exploration and sustainable utilization of space resources for the benefit of humankind

Five Strategic Pillars

- 1 Ensure national political support and promote international cooperation
- 2 Build clear legal framework and engage internationally
- 3 Promote long-term public support and workforce engagement through education and R&D
- 4 Provide dedicated support for industrial research and development activities
- 5 Develop long-term funding instruments

Luxembourg has been promoting space resource utilization nationally and internationally, on all levels



International Engagements



ESA



European Union



United Nations

Bilateral agreements signed



Promote investment in ISRU
Develop ISRU for exploration
Need for international framework

Looking for suitable projects of common interest, in particular in utilization of Space resources

International media exposure

Organization and Engagement in Various Events



International Advisory Board



Luxembourg proceeds with a step-by-step approach to build a clear international framework on space resources



National law on the exploration and use of space resources (August 2017)



A first step for future space resources activities :

- *provides legal security and legal clarify for private operators*
- *Recognizes that space resources are capable of being owned*
- *fulfills its obligations under Art. VI of the OST (authorization and supervision)*

Hague International Space Resources Governance WG



Luxembourg strongly supports the activities of this working group.

A set of 20 building blocks were agreed at the last meeting in April, covering:

- *Non-interference*
- *Priority rights*
- *Period of use*
- *Environmental issues*
- *Assistance to developing countries*
- *Framework for dispute resolution*
- *... and many other topics.*

UN-COPUOS



Luxembourg encourages discussions on space resources exploration and utilization in all relevant international fora, in particular in the Legal Subcommittee of the UN-COPUOS.



The European Space Agency is a key partner for Luxembourg and more and more active in space resources



Specific agreement signed in 2017



Key studies developed and implemented together.

Cooperation in events

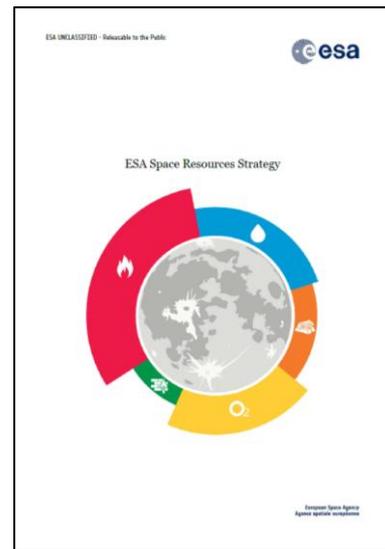
2018:



2019:



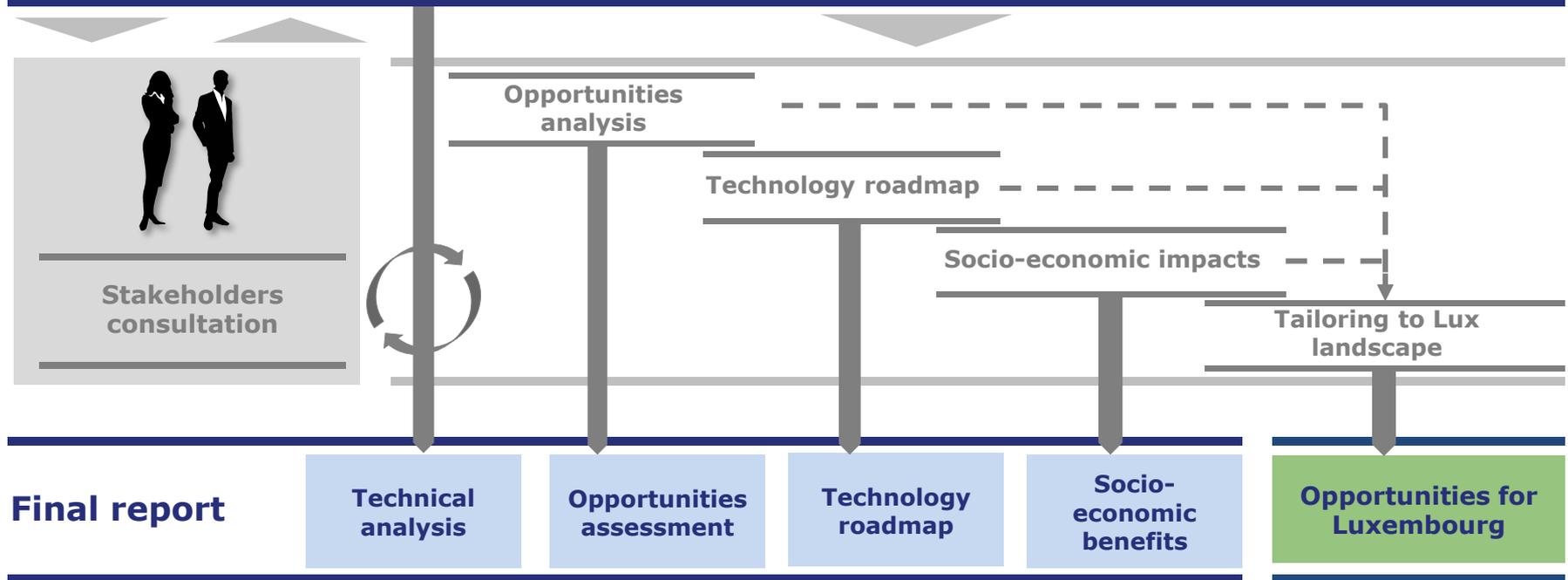
ESA Space Resources Strategy published in May 2019



In 2018, we ran a study to analyze the likely market, technology and socio-economic impacts, allowing us to focus our initiative



Technical note



The potential value chains for SRU were characterized on the basis of applications, resources and mission profiles



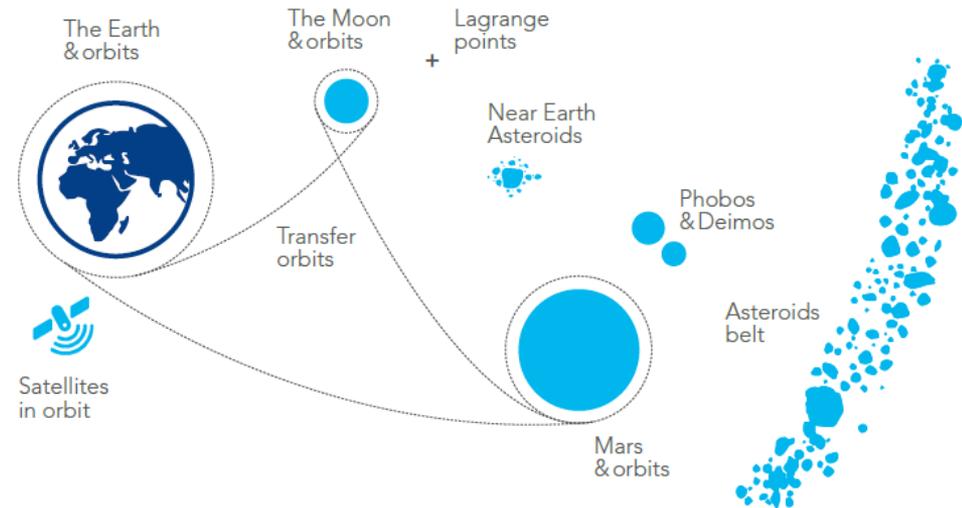
1 Applications

- Life support to astronauts
- Propellant for launch vehicles and other space vehicles
- Construction of in-situ infrastructure
- Radiation shielding
- Manufacturing of equipment in space
- Earth-based use of Platinum Group Metals (PGM)

2 Resources

- Water, and others: H, O, N, C
- Methane
- Metals (Fe, Ni, Co)
- Regolith
- Platinum Group Metals (PGMs)

3 Mission profiles



Celestial bodies considered for the assessment of the space resources utilization value chains.

SRU value chain

Prospect

Establish

Mine

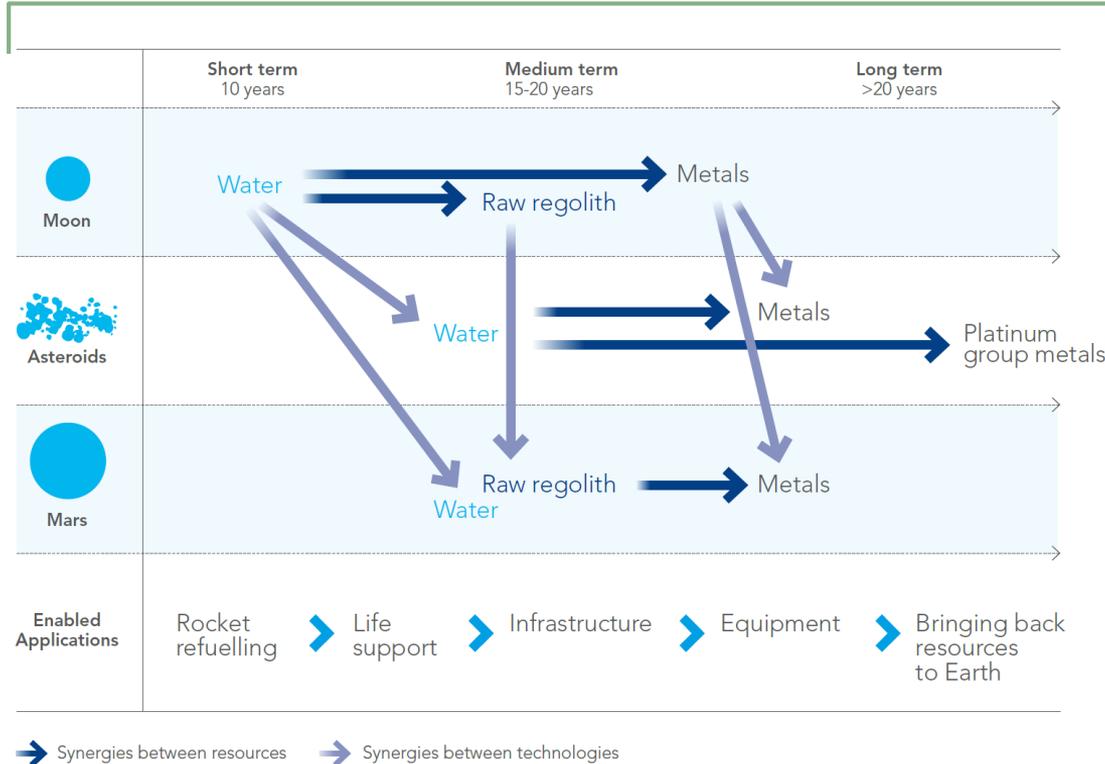
Transport

Refine

Manufacture

Supply

The main drivers and risks have been discussed, leading to conclusions which reflect the highest consensus within experts



- SRU **will support exploration missions'** feasibility, cost efficiency and autonomy
 - Provision of **propellant** will be the first application to target
 - Scientific missions led by **space agencies** will be the first customers
 - **Earth mining industry** needs to be involved for their expertise and practical understanding
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- The challenge in refining the "geological" knowledge remains a strong barrier
 - Strong **scepticism** on the realism of bringing back PGM

15 key technologies were selected and analyzed, with impact on multiple SRU value chains

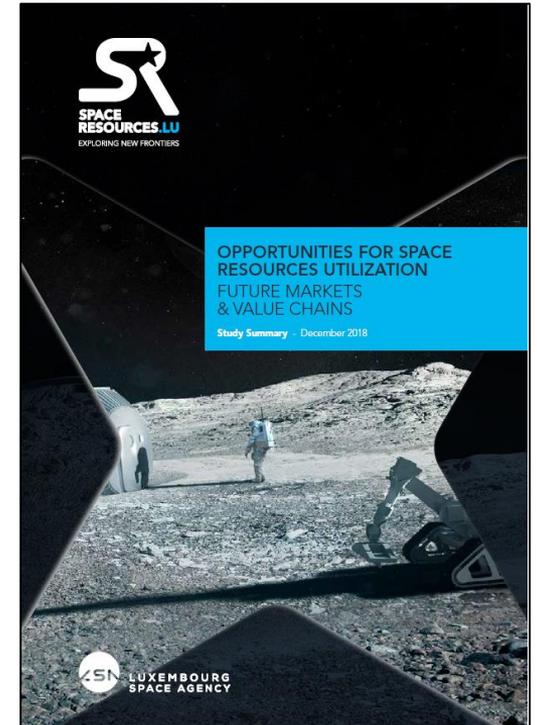


- 1 Mineralogical analysis
- 2 Robotic excavation (partial gravity)
- 3 Regolith de-volatilization/water extraction (partial gravity)
- 4 Crushing, sieving, separation (partial gravity)
- 5 Production of Oxygen from Regolith and other non-volatiles sources
- 6 Directed Energy deposition AM and soil passivation (metal, regolith)
- 7 Long-duration, reliable, heavy duty robotic platform in dusty environment
- 8 Fully autonomous SRU spacecraft/vehicles/plants
- 9 Robotics operating in permanently or quasi-permanently shadowed regions
- 10 Supervised autonomy for Delay mitigation
- 11 Object Recognition and Pose Estimation
- 12 Fusing vision, tactile and force control for manipulation
- 13 Human-like dexterous manipulation in space
- 14 Full immersion, tele-presence with haptic and multi modal sensor feedback
- 15 Fuel depots

Key outcomes and messages of the study



- **SRU** must and will materialise. **It is only a matter of feasibility timeline.**
- **Substantial costs savings** and added **autonomy** for space missions.
- **Prospecting** is key!
- Collaboration between the **space and the terrestrial mining industries** should be encouraged.
- Support activities, such as **legal and financial frameworks** or provision of **deep space communications** and **energy**, will be mandatory enablers.
- **Public actors** are expected to play a key role in the support of SRU activities, mostly as being the **first customers.**



Thank you for your attention!



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