Synergetic Material Utilization – Combining ISRU and ECLSS

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Introduction: Sustaining exploration of the solar system requires a large amount of material and an even larger amount of propellant to transport this material out of Earth's gravity well and onwards to its destina-tion. Despite recent advances in lowering the launch costs by applying methods such as reusability of the launch system, transferring material from Earth to space is still very costly with several thousand to tens of thousands Euro per kilogram into a low-earth orbit and transportation to Moon and Mars cost-ing a multitude of that. Although, current predictions foresee a further reduction in launch costs in the near future to tens of Euro per kilogram [1], each kilogram of material transported from Earth to LEO remains valuable and when transported to Moon or Mars the value is even higher.

Human space exploration requires a significant amount of resources such as food, water and oxygen. Waste products such as metabolic waste, polluted water and carbon dioxide are produced by the as-tronauts. Life support engineers are developing systems and processes to recycle and to regenerate as many resources as possible, also known as 'closing the loops', in order to reduce the material supplied from Earth to enable sustainable human space exploration of the solar system.

Our solar system is full of resources that potentially can be exploited to greatly reduce the material re-quired to be launched from Earth. Among these resources are water ice, hydrates, metals, regolith, rare earths, chemical compounds, volatiles and rare isotopes. Utilizing space resources would enable e.g. propellant production, in-space manufacturing or the construction of large structures which would oth-erwise be very expensive or not possible at all with material launched from Earth.

The concept of Synergetic Material Utilization (SMU) combines In-situ Space Resources Utilization (ISRU) and Environmental Control and Life Support System (ECLSS) engineering approaches to lower the material supply required from Earth.

In 2021 a research group was founded at the German Aerospace Center's Institute of Space Systems in Bremen, which focuses on the Synergetic Material Utilization concept.

Synergetic Material Utilization Concept: ECLSS and SRU are two space engineering fields with increasing importance in the future to enable sustainable exploration of the solar system. In both fields processes and techniques are applied to ex-tract, produce, utilize, consume and regenerate resources albeit with different purposes. The goal of ECLSS engineering is to enable human survival in space with as little resources as possible in order to reduce cost for resupply from Earth. SRU on the other hand uses local resources to produce a wide range of materials for different applications, but also with the goal of reducing the cost of launching the material from Earth.

Despite the similarities among both fields, ECLSS and SRU scientists and engineers often disregard the other research field. Almost all case studies of near-term SRU rely purely on robotics and automation without the assistance of humans on-site. Often the presence of humans is rejected with the argument regarding the costs involved of setting up the required ECLSS infrastructure. ECLSS case studies of fu-ture Moon or Mars space exploration systems, on the other hand, mostly neglect the utilization of local resources because of the fixation on regeneration and the 'closing the loop' principle, but also by using the cost argument for setting up a SRU infrastructure.

Synergetic Material Utilization is the approach of combining ECLSS and SRU engineering in order to exploit the many synergies among both fields to enable sustainable exploration of the solar system.

Synergies between ECLSS and SRU are:

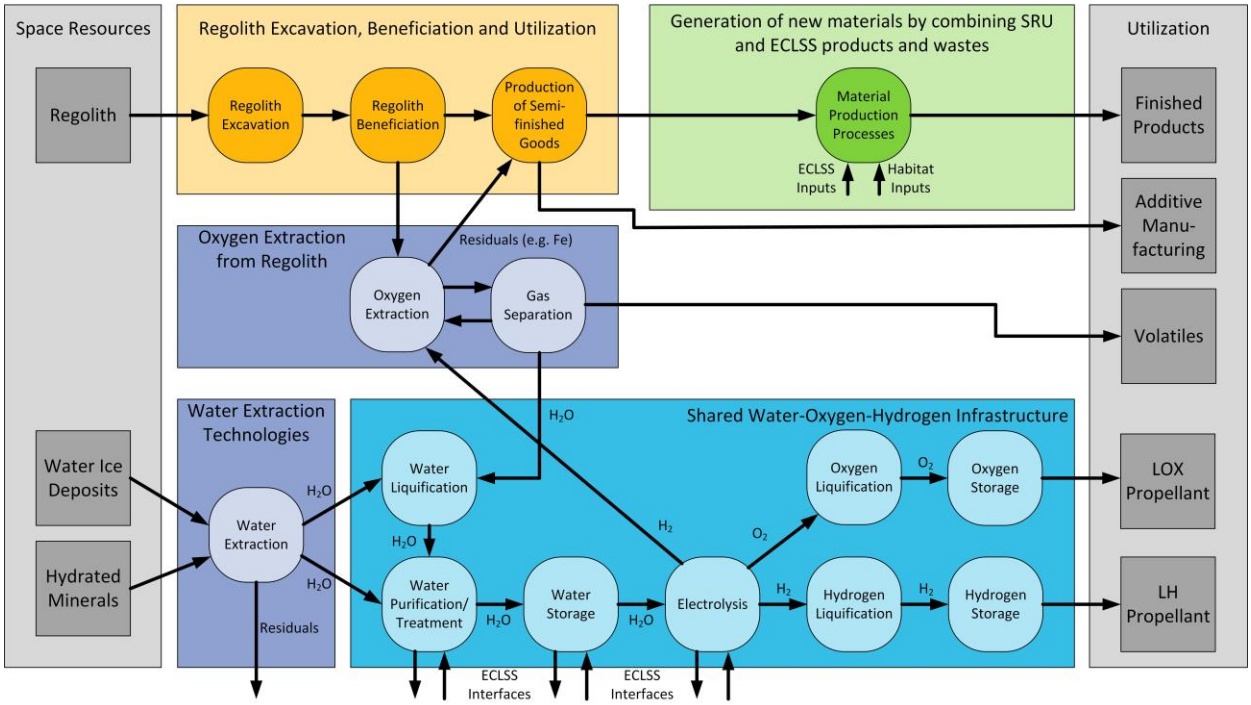
- Shared processes and technologies,
- Common materials processed,
- Common products generated,
- Cross-utilization of products and resources,
- Combination of materials from various sources.

Planned Activities of the SMU Research Group at DLR: The SMU research group at the DLR Institute of Space Systems was established in 2021 with approval of the Director of Space Research of DLR. This research group focuses on the combination of SRU technologies with life support systems and processes in order to exploit synergies. Thus, a holistic approach for resources management during future space exploration missions is persecuted.

Concrete activities for the next 3-4 years are technology developments for regolith beneficiation, oxygen

extraction from regolith and water extraction for in-situ propellant production. These developments are complemented by a system study for a shared water-hydrogen-oxygen infrastructure with ISRU and ECLSS elements for a future habitat and by concept studies for the in-situ production of new materials based on ISRU and ECLSS products.

The schematic below illustrates how the different topics of the research group are connected to each other and also where the interfaces with the ECLSS and habitat are.



References:

[1] Jones, H. W. (2018), 'The Recent Large Reduction in Space Launch Cost', *48th International Conference on Environmental Systems, 8-12 July, Albuquerque, New Mexico*.