ISRU: An approach to change and knowledge gaps to fill for viable processes in space. A. Meurisse[1] and J. Carpenter[2], [1]Research Fellow, European Space Agency - ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, Netherlands, alexandre.meurisse@esa.int, [2]Scientist, European Space Agency - ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, Netherlands).

Introduction: In-Situ Resource Utilization (ISRU) is once again seen as a way to facilitate the exploration of the solar system , particularly at the Moon and Mars. For reducing the cost, limiting the up-launch mass from Earth or creating a more autonomous and safe environment for the astronauts and other explorers, the versatility of ISRU appears as a strong asset to any long crewed exploration mission. In order to play their roles, the ISRU processes have to survive the harsh space environment which includes dust, radiations and cyclic extreme hot and cold temperatures. ISRU will however not take part in a mission plan before the reliability of the processes over time with a multi-compound feedstock material – not thoroughly characterized – has been significantly proven. Works towards this goal, have started around 1963, over the first *Working Group on Extraterrestrial Resources* [1], and yet, there is still a long way to go before using technologies utilizing local materials in space missions.

This work aims at stepping back to analyze what went wrong, what could be done better in the future in the development of ISRU technologies and processes, and where should be the particular research focus for the next decade.

A Change of Focus: The ISRU development strategy has so far been engineering-driven. Designing and building terrestrial demonstrators for oxygen production [2] and construction [3] are the focus of the funded studies as they provide visibility and proofs of concept of the different ISRU processes. The Technology Readiness Level (TRL) reaches 3 or 4 and then stops. The step to TRL 5 involves the need of a *relevant environment* according to ESA and NASA definitions, meaning at least the use of relevant analogue material and vacuum. These two requirements have never been met so far: the simulants material never seems to be representative enough of the extraterrestrial material and the vacuum is only applied at lab-scale, with a pressure usually down to 10^{-5} mbar when the lunar vacuum is about 10^{-12} mbar. This recurring issue for all kinds of ISRU processes may be an indication that a rationale exists in changing the strategy used so far in ISRU research.

One new option is to have materials science-driven ISRU research, targeting a deeper understanding of the existing processes at the mineral level. An extensive fundamental knowledge of the physicochemical properties of the different extraterrestrial minerals and of the thermodynamic involved in ISRU processes may be more beneficial in the long run that the trial-and-error approach used heretofore with various simulants.

Another option would be to concede that it is not feasible to reproduce the lunar or Martian conditions for a reasonable cost and that ISRU technologies should be tested – as the acronym implies – *in-situ*. Demonstration missions could fill key knowledge gaps in short term for lunar ISRU research, as is being developed commercial landers which could offer missions opportunities.

End-to-end consideration: ISRU could only be taken into account for a mission when the end-to-end processes will be fully covered. Most of past and current ISRU researches omit the potential presence of compounds like Sulfur in the feedstock which could react with the process gas (e.g. hydrogen), the binder or the equipment. After a reduction process, the produced water is usually not characterized and information regarding its use for life support or for an electrolysis step remains unknown. Radiation impact on the end-product has also so far been poorly considered. Filling these pre- and post-process gaps could be done now, on Earth, and would support the overall use of local resources for a sustainable human exploration.

References:

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