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PATHWAYS TO SUSTAINABILITY IN LUNAR EXPLORATION ARCHITECTURES

Abstract

With an ever increasing geopolitical relevance of human lunar exploration, the world's space agencies show an increasing interest in its implementation in the very near term. In August 2020 the International Space Exploration Coordination Group has published a supplement to its Global Exploration Roadmap that focusses on the envisioned future lunar architecture based on objectives of sustainability and benefit generation. Here we apply quantitative benefit assessment methods and a high-level parametric cost model to the architecture in order to analyse the effectiveness of two methods of increasing sustainability: in-situ resource utilisation and reusability. We find that both measures are effective, but require very different approaches to the investment strategy. While the utilisation of lunar resources achieves the lowest per-mission cost in the utilisation phase, it requires significant upfront investments into the development of specific equipment and its transportation. Depending on the choice of model parameters, the return of investment in transporting additional equipment might be achieved only after more than 30 human missions in the utilisation phase, even when neglecting the development cost of surface infrastructure. The investment in even partially reusable vehicles, however, is returned already after the first utilisation mission, but it does not achieve the same performance in terms of lowering the cost of utilisation missions if not combined with the use of lunar resources. We thus recommend space agencies to carefully consider the timing of investment into resource utilisation with respect to the benefit it generates.