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Systems and Infrastructures to Implement Sustainable Space Development and Settlement - Technologies (2B)

Author: Mr. Tim Altorfer
ZHAW – Zurich University of Applied Sciences, Switzerland, tim.altorfer@zhaw.ch

Mr. David Dudli
ZHAW – Zurich University of Applied Sciences, Switzerland, david.dudli@zhaw.ch
Dr. Marius Banica
ZHAW – Zurich University of Applied Sciences, Switzerland, marius.banica@zhaw.ch
Prof. Markus Weber Sutter
ZHAW – Zurich University of Applied Sciences, Switzerland, markus.weber@zhaw.ch
Mr. Dario Wichser
ZHAW – Zurich University of Applied Sciences, Switzerland, dario.wichser@zhaw.ch
Dr. Matteo Madi
Switzerland, madi@sirin-os.com
Prof. Raffaele Mezzenga
ETHZ, Switzerland, raffaele.mezzenga@hest.ethz.ch
Dr. Yang Yao
ETHZ, Switzerland, yang.yao@hest.ethz.ch

CONCEPTUAL DESIGN OF A LIQUID WATER STORAGE SYSTEM FOR LUNAR LIFE SUPPORT AND EXPLORATION

Abstract

The Global Exploration Roadmap expects human missions to the lunar surface around 2030. Among local resource utilization, the extraction of propellant and life support consumables, such as water and oxygen, are high priorities. Water is considered a bi-product of propellant production and is also essential for sustained and sustainable human presence on the Moon. Recent advances in nanotechnology now allow the storage of liquid water at temperatures as low as -120C (Manni et al., Nature Nanotechnology, vol. 14, pp. 609-615, 2019; Yao et al., Nature Nanotechnology, vol. 16, pp. 802-810, 2021). The present paper proposes to exploit this technology in the design of future lunar bases, such that lunar water ice is stored in liquid form, for both life support and propulsion, in tanks external to the habitats. The technology is based on lipidic mesophase nanoconfinement of the water, and, therefore, requires specialized processing units for lipid enrichment and separation. The main differentiating features of this technology are that it (1) does not require any supply of energy for maintaining water in its liquid state; and (2) is Off-Earth manufacturable—the water containers can be 3D printed or built through in-situ additive manufacturing processes using local materials. The lipids are recyclable and can be carried to the Moon as a peripheral payload, e.g. on board the European Large Logistics Lander (EL3), which is aimed to deploy cargo supplies and instrumentation on the lunar surface by the later 2020s. This work focuses on the life support part of a possible lunar liquid water storage system. It discusses enrichment and separation unit design and closed loop operation, system sizing, wastewater treatment, and key component selection (heat exchangers, pumps, valves, etc.). Tank development and IC are also addressed. Emphasis is placed on using commercially available solutions whenever possible to ensure low development costs.

A dynamic numerical system model is developed using EcosimPro with the ESPSS library. The latter was designed for the simulation of space propulsion systems. The simulations provide estimates for operating performance, including electrical, thermal and pressure budgets. Relevant material properties are obtained from experiment. We conclude that the proposed system would integrate well with currently planned lunar base designs in terms of electric energy demands and operating performance, while at the same time allowing easy storage of water for life support and as a precursor material for lunar launch vehicle fuel production.