In-Situ Propellant Architecture for Near-Term Lunar Missions

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Off-planet manufacture of propellants is critical to the sustainability of space exploration. But no minimum viable product for in-situ propellant production exists for a location such as the Moon. This is primarily due to the lack of storability for typical in-situ derived propellants such as hydrolox, the cryogenic bipropellant of liquid oxygen and hydrogen. Other cryogenic fuels that have additional elements, such as methane, are difficult to create in-situ due to resource limitations. Most storable alternatives to cryogenic propellant are toxic and also require hard-to-find elements in-situ.

Orbit Fab has undertaken a propulsion system trade study, summarized in Table 1. **One nontoxic, storable monopropellant stands out for near-term in-situ resource utilization (ISRU): high-test peroxide (HTP),** which can be made directly from water. HTP catalytically decomposes into oxygen and water vapor and can provide high-density specific impulse to power a lunar or small body ascent vehicle.

Table 1: In-situ propulsion system trade study shows the advantages of HTP monopropellant

Characteristic	Solar Electric	Direct Solar Thermal	Chemical	Water Solar Thermal	Cryo ISRU	Biprop HTP/ Hydrocarbon ISRU	Monoprop HTP ISRU
Complexity	low	med	low	med-high	high	med- high	low-med
Ascent Thrust	no	no	yes	no	yes	yes	yes
Solar Array / Collecting Area	high	high	low	high	high	medium	medium
ISRU	no	yes	no	yes	yes	yes	yes
Storable	yes	yes	yes	yes	no	yes	yes

Orbit Fab is developing a system that radically simplifies the production of hydrogen peroxide while increasing its availability both on and off Earth. A diagram of this system, currently at TRL 3, is shown in Figure 1. Peroxide is continuously produced from purified water using a proton exchange membrane (PEM) cell (Figure 2) developed by the Wang Group at Rice University and licensed to Orbit Fab.[1] The peroxide is concentrated to 90–98% HTP and stored. **This HTP production system could enable in-situ HTP use within a few years.** An MVP development timeline is presented in Figure 3 that will raise the system to TRL 6. Past work by John S. Lewis analyzed storable propellant feasibility for in-situ utilization,[2] which will catalyze Orbit Fab's efforts to further increase the TRL for spaceflight. Figure 4 shows a potential lunar ISRU sample return mission demonstrating the capability of Orbit Fab's HTP production system. A 250 kg dry mass (m_{dry}) lunar ascent vehicle returning from the lunar surface to low-Earth orbit rendezvous requires 1359 kg of HTP monopropellant, assuming specific impulse (I_{sp}) of 150 s and Δv of 2.74 km/s. This is calculated using the ideal rocket equation (Equation 1), where m_{wet} is fueled vehicle mass and g_0 is standard gravity.

$$\Delta v = I_{sp} g_0 \ln(m_{wet}/m_{dry}) \qquad (1)$$

The HTP used for this mission's lunar ascent and return to LEO can be made on the lunar surface from water using the Orbit Fab system.

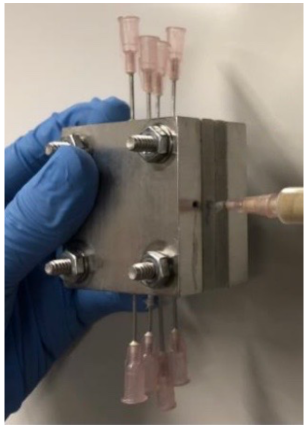

Figure 2: Orbit Fab is building upon Rice University Wang Group's patented peroxide PEM cell

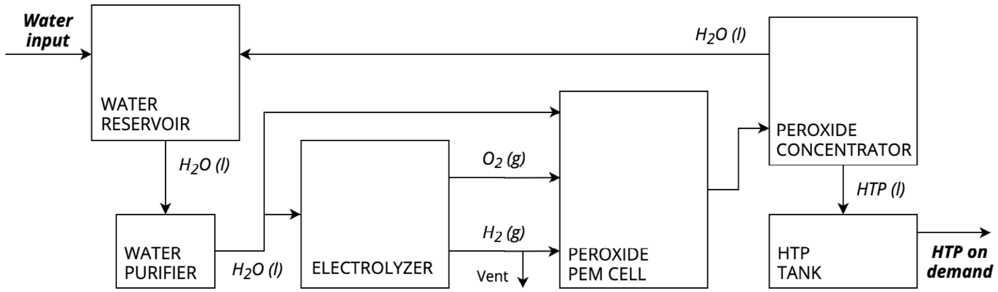

Figure 1: Notional block diagram highlighting major subsystems of water-to-HTP system

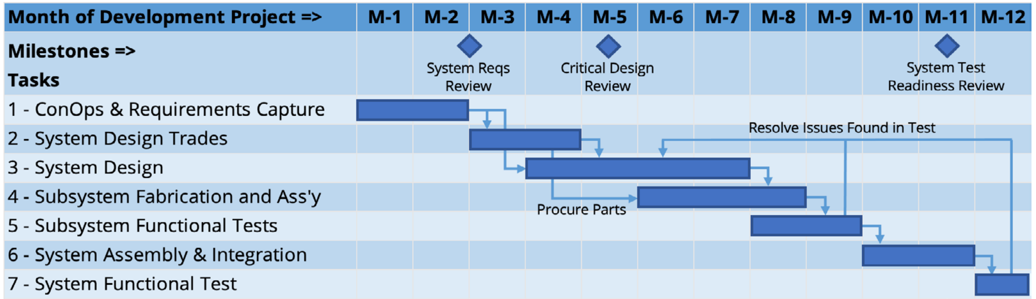

Figure 3: Milestone schedule from requirements capture to TRL 6 HTP production system MVP in a 12-month development period

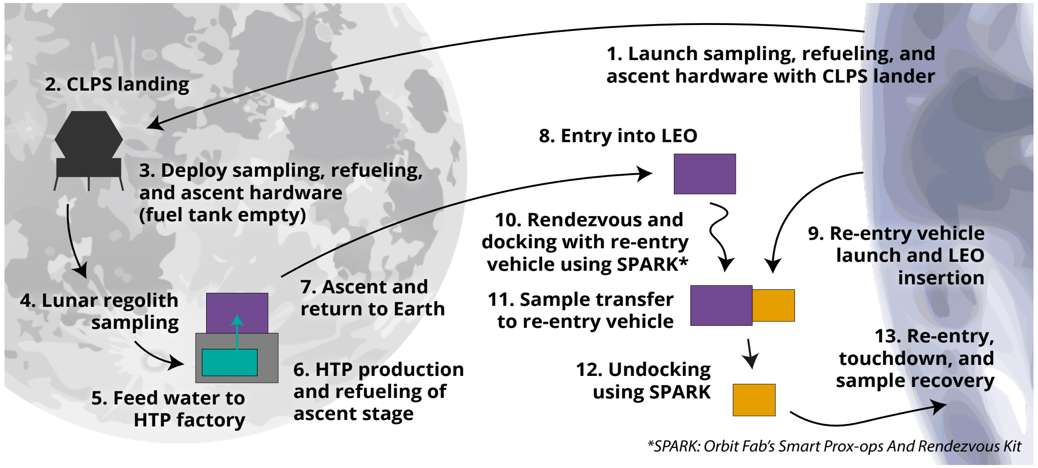

Figure 4: Potential lunar mission with sample return and HTP production system-enabled ascent vehicle refueling could be ready to fly as early as 2023

References

[1] Xia, Chuan, et al. "Direct Electrosynthesis of Pure Aqueous H2O2 Solutions up to 20% by Weight Using a Solid Electrolyte." Science, vol. 366, no. 6462, Oct. 2019, pp. 226–31
[2] Lewis, John S. "In-Space Production of Storable Propellants." 1 Mar. 2016.