A Flexible System for In-Situ Propellant Production

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Introduction

Producing propellant on the Lunar surface is one of the most important milestones to enable a permanent, thriving in-space economy. An increasing focus from government, commercial, and academic sectors is being placed on the development of in-situ resource utilization (ISRU) systems, particularly for propellant production. Many barriers stand in the way of realizing ISRU propellant production systems on the surface of the Moon. Past works have focused on issues such as the difficulty of storing cryogenic water-based propellants. This work uses the Orbit Fab HTP Production System to explore two other challenges related to ISRU propellant production: the difficulty of securing funding for ISRU technology development, and the issues associated with developing ISRU systems in isolation with insufficient thought given to how they will interect within an architecture.

The In-Situ Propellant Production System

This work presents a flexible propellant production system that can accelerate the adoption and viability of propellant production in a variety of ISRU architectures while enabling increased access to funding opportunities based on the ability to find product-market fit on Earth. Previous Orbit Fab publications have discussed the benefits of high-test peroxide (HTP) for ISRU, including storability, low cost of production, and usability for Lunar ascent.[1,2] Orbit Fab is designing a lightweight and portable HTP Production System[3] that produces HTP from a variety of different inputs.. The basic chemical formula for HTP production (water conversion to pure peroxide) is as follows: $2H_2O \rightarrow H_2O_2 + H_2$ Each configuration of the HTP Production System described in this poster is based on the elemental inputs to produce HTP, hydrogen and oxygen, as seen in this formula.

HTP Production System: Configuration A

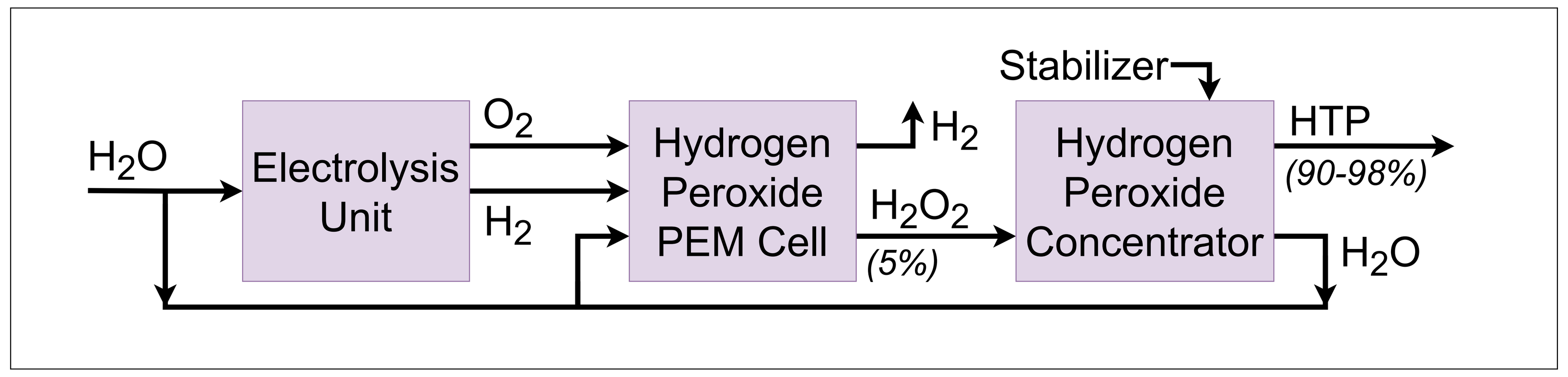

Figure 1. High-level block diagram of Orbit Fab system which produces 90-98% HTP and byproduct hydrogen from a water input.

Configuration A is simple: water in, HTP out. Along with HTP, hydrogen is produced as a byproduct. **This configuration is ideal for ISRU scenarios where water has been extracted from regolith and purified.** Water is electrolyzed internally to the HTP Production System prior to being converted to hydrogen peroxide and concentrated into HTP. The hydrogen byproduct, which is common to all configurations discussed here, can then be used for other processes, such as in a Sabatier reactor for water and methane production, or for water production via hydrogen reduction. Table 1 shows a rough estimate of the size, weight, and power (SWaP) for an example system.

Table 1. Size, weight, and power for a system which will produce 10 kg of 90-98% HTP per day from a water input.

Size	Weight	Power
0.125 m^3	425 kg	11.2 kW

HTP Production System: Configuration B

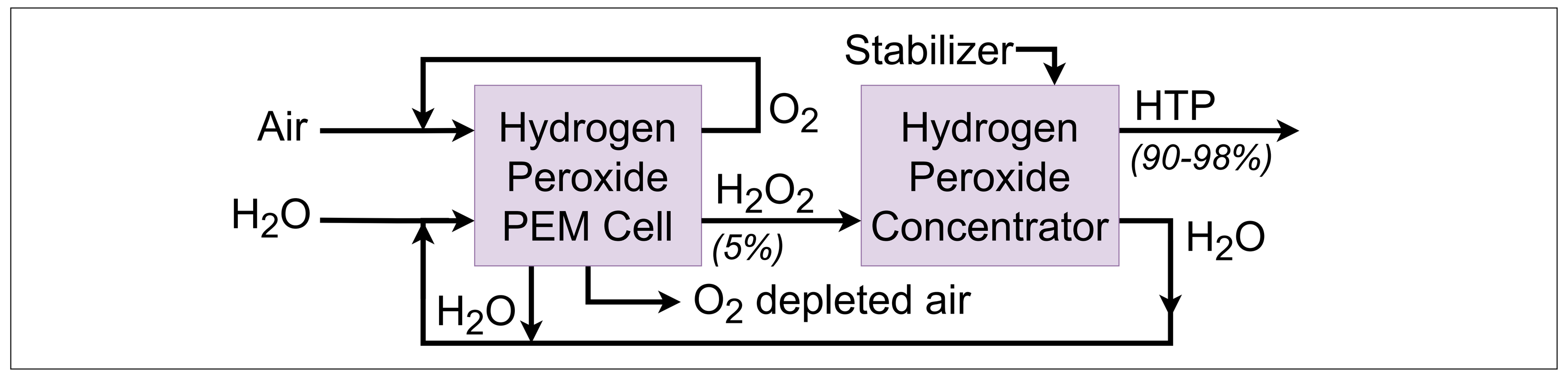

Figure 2. High-level block diagram of the Orbit Fab system which produces 90-98% HTP and byproduct depleted air from inputs of water and air.

Configuration B enables the system to accept inputs of water and air. **This system is applicable to situations on Earth where low-cost, on-demand HTP production is needed.** HTP today is generally expensive or only available in bulk. This system enables a far lower cost and volume of HTP production. Unlike Configuration A, Configuration B does not require electrolysis, reducing system energy requirements. An HTP Production System in Configuration B could find product-market fit on Earth, while developing the same technology that will be used for low-cost, on-demand production of HTP on the surface of the Moon.

Table 2. Size, weight, and power for a system which will produce 10 kg of 90-98% HTP per day from inputs of water and air.

Size	Weight	Power
0.0625 m^3	65 kg	7.7 kW

HTP Production System: Configuration C

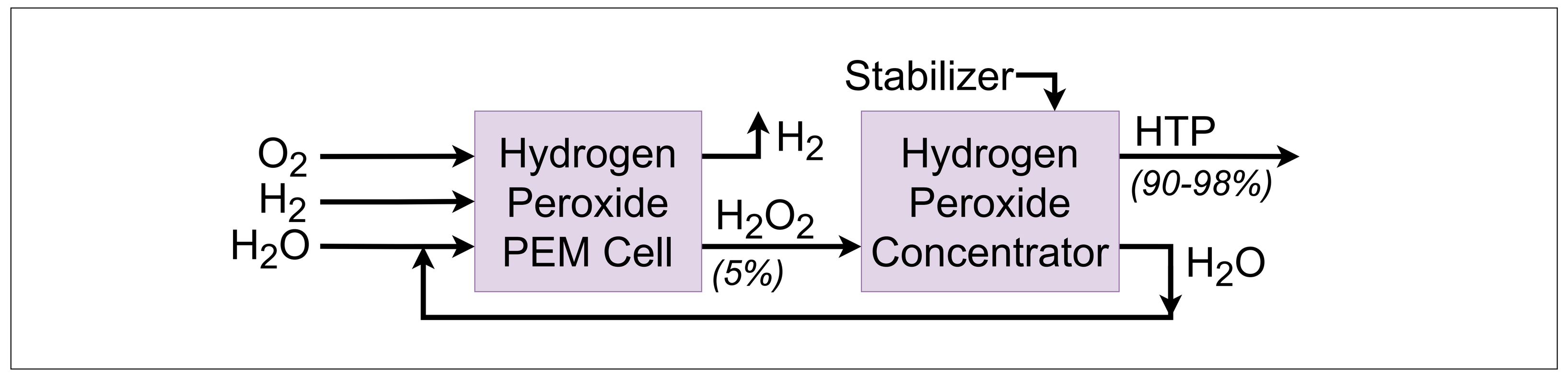

Figure 3. High-level block diagram of the Orbit Fab system which produces 90-98% HTP and byproduct hydrogen from inputs of oxygen, hydrogen, and water.

Configuration C accepts inputs of water, hydrogen, and oxygen. In this configuration the HTP Production System is built without an electrolyzer, simplifying the system and reducing energy requirements. **This configuration is useful when another ISRU system is already producing hydrogen and oxygen, and in other situations where all three of these components are available, both on and off Earth.**

Configuration C has a similar size, weight, and power to Configuration B, as it is composed of the same subsystems in a different configuration. As Tables 1 and 2 demonstrate, the electrolyzer is a large contributor to the SWaP of the system. If oxygen and hydrogen can be sourced from other ISRU processes, the system SWaP will be reduced. The electrolyzer SWaP presented here is based off of the OGA electrolyzer on the ISS, so future efficiency gains will lower system SWaP requirements

Why is System Flexibility Important?

Orbit Fab's goal is to build the propellant supply chain in space. A propellant production system that is adaptable to many terrestrial and extraterrestrial environments will increase the availability of propellant on Earth and in space, while decreasing its cost. Widely available propellant in space and on the Moon will catalyze the in-space economy and enable missions to achieve Earth-independence sooner.

Combining the various HTP Production System configurations with flexible ISRU architectures creates synergistic effects, promoting the use of byproducts from processes while increasing each system's yield, efficiency, or usefulness. This synergy with the HTP Production System is the topic of ongoing Orbit Fab efforts which will build on this work and be explored in future publications.

The focus on flexibility described above is applicable to systems across the ISRU spectrum. Systems which can find funding on Earth are more likely to reach the stage of development necessary to deploy on the Moon. Furthermore, a system which is flexible in its configuration will be able to better satisfy customer needs on the Moon, enabling it to find a wider variety of customers and therefore funding. The cislunar economy is nascent and buyers and sellers are just beginning to find each other. **System flexibility will improve the viability of companies and their technologies and make it easier for buyers and sellers of space resources to connect.**

Conclusions

- Propellant produced on the Moon will lower the cost of access to space and enable a permanent and thriving in-space economy.
- The Orbit Fab HTP Production System can be configured in various ways to satisfy technical and business needs on Earth, in space, and on the surface of the Moon.
- Electrolysis is a SWaP driver, and certain configurations of the HTP Production System avoid the need for an electrolyzer.
- Flexibility in ISRU systems enables technologies to gain traction and use on Earth prior to being deployed to an in-situ environemnt.
- Flexibility in ISRU systems enables greater interconnection opportunities and a more robust architecture to promote a sustainable Lunar presence.

References

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2. C. Geiman, J. Bultitude, D. Faber, Z. Burkhardt, G. Kendall-Bell, A. O'Leary, A. Deuitch, E. Spessert, *Small Body Ascent Enabled by In Space Resource Derived and Produced Hydrogen Peroxide*, (2021).
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