NEW POWER SOURCES FOR SURVIVING THE LUNAR NIGHT. Erik J. Brandon[1], William C. West[1], Dane Peterson[1], Madison Hunter[1], Hui Li Seong[1], Jasmina Pasalic[1], Keith Billings[1], John-Paul Jones[1], John Paul Ruiz[1] and Frank Guillen[1]. [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109.

Introduction: Different strategies may be employed to support the survival of landed missions through a lunar night. Options for system level hibernation at low temperatures are available, but this precludes executing significant operations during the lunar night, and the approach may not be feasible with all payloads (particularly those with temperature sensitive instruments). Use of solar arrays with standard space rated rechargeable Li-ion batteries is mass prohibitive for smaller landers, requiring >100 kg of batteries to supply even modest levels of electrical heating through the lunar night. Although alternate sources relative to Pu-238 heater units are under development, use of radioisotopes for heating could impose particularly challenging cost and regulatory constraints for future commercial landers. Several approaches are under development at the Jet Propulsion Laboratory (JPL), to address both survival and operations through the lunar night. These include high specific energy primary and rechargeable batteries, and chemical heat sources.

High Specific Energy Primary Batteries: There have been significant recent developments in advanced high specific energy Li/CF_x cells [1-3]. JPL has worked with primary cell vendors Rayovac and EaglePicher Technologies, to develop a next generation, high performance cell. These cells employ advances in aluminum packaging combined with improved electrode processing to support cell level solutions which can power a 20+ day Europa Lander mission operating on primary batteries alone within a reasonable mass envelope. An extensive test campaign was developed to evaluate these advanced cells with respect to performance over a range of temperatures, storage losses and radiation levels. Of particular interest is the significant level of thermal power generated by these cells based on the inherent cell chemistry; this is typically viewed as a detriment for Earth applications but becomes an asset in this application. This, combined with demonstrated cell level specific energies of >700 Wh/kg and targeted pack level specific energies of 500-600 Wh/kg, results in a viable power source for lunar night survival. These cells can provide both sufficient electrical power and heat to support operations at modest temperatures without radioisotopes.

Chemical Heat Based Sources: Another approach under investigation focuses on the use of a highly exothermic reaction to generate high quality thermal power. This thermal power can be utilized for direct heating of lander sub-systems, and to generate electrical power through an appropriate thermal-to-electric conversion technology. A system concept has been developed and sub-system level testing has been performed on such a technology, the Chemical Heat Integrated Power Source (CHIPS) [4]. In this concept, heat is generated by the exothermic reaction of Li metal and the oxidizer SF_6. A design for a system that could be integrated with a Commercial Lunar Payload Services (CLPS) lander has been developed (Fig. 1), and sub-scale system testing has been performed. This includes heat pipe testing as well as testing of the reaction for extended run times. Development efforts are focused on achieving a system level performance of >800 Wh/kg of combined thermal and electrical power.

High Specific Energy Rechargeable Batteries: Ultimately, high specific energy rechargeable solutions are required for surviving multiple lunar night cycles. This requires cell and pack level technology, that far exceed the 150 Wh/kg space rated battery modules flown on typical missions. JPL is currently assessing several such high specific energy cells (300-400 Wh/kg) for supporting lunar night survival missions, charged by solar arrays during the lunar day.

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References: [1] HL Seong, et al. (2022) *J. Electrochem. Soc.*, *169*, 060550. [2] J.P. Jones, et al. (2020) *J. Power Sources*, *471*, 228464. [3] F.C. Krause, et. al., (2108) *J. Electrochem. Soc*., *165* A2312 (2018). [4] K. Anderson, E.J. Brandon, et al. (2012) *50th ICES*, Abstract # ICES-2021-163.

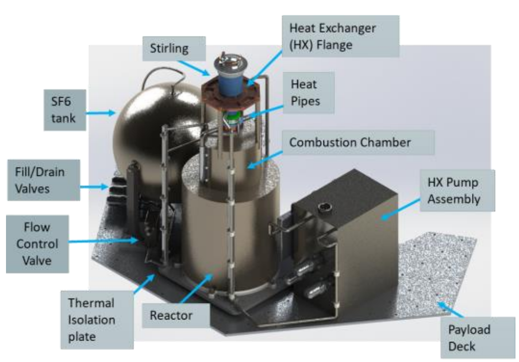

Fig. 1. System level conceptual CHIPS design, on the deck of a notional lunar lander payload deck.