THE USE OF NUCLEAR PROPULSION, POWER AND "IN-SITU" RESOURCES FOR ROUTINE LUNAR SPACE TRANSPORTATION AND COMMERCIAL BASE DEVELOPMENT

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Abstract

Nuclear propulsion and power systems, together with "lunar-derived" oxygen (LUNOX) and/or propellants produced from possible lunar polar ice (LPI) deposits, offer the potential for routine commuter flights to future lunar settlements engaged in a variety of commercial enterprises. Iron- rich volcanic glass, or "orange soil," discovered during the Apollo 17 mission to the Taurus-Littrow Valley, has produced an appreciable oxygen yield (5wt%) in recent hydrogen reduction experiments conducted by NASA. The development and utilization of LUNOX or LPI-derived propellants would eliminate the need to transport liquid oxygen (LOX) and hydrogen (LH_2) supplies from Earth and could dramatically reduce the size, cost and complexity of lunar space transportation systems. The "LOX-augmented" NTR concept (LANTR) is an important propulsion technology option that can exploit both the high performance capability of the conventional LH_2-cooled NTR and the mission leverage provided by "in-situ" lunar-derived propellants in a unique way. LANTR utilizes the large divergent section of its nozzle as an "afterburner" into which oxygen is injected and supersonically combusted with nuclear preheated hydrogen emerging from the engine's choked sonic throat -- essentially *"scramjet propulsion in reverse.*" By varying the oxygen-to-hydrogen mixture ratio, the LANTR engine can operate over a wide range of thrust and specific impulse (Isp) values while the reactor core power level remains relatively constant. The thrust augmentation feature of LANTR means that "big engine" performance can be obtained using smaller, more affordable, easier to test NTR engines. The use of high-density LOX in place of low-density LH_2 also reduces hydrogen mass and tank volume resulting in smaller space vehicles. An implementation strategy and "evolutionary" mission architecture is outlined which utilizes Shuttle-derived heavy lift vehicles for Earth launch and conventional, high thrust NTR-powered lunar transfer vehicles (LTVs) for crew transport. Low thrust, high Isp, nuclear electric propulsion (NEP), which is ideal for cargo transport, is used to deliver "modular" surface reactor and propellant production units with the intent of supplying LUNOX (and LH_2 from LPI if its exists) to chemical propulsion landing vehicles (LLVs) initially and then to the LTVs. Once LUNOX becomes available in low lunar orbit (LLO), monopropellant NTRs would be outfitted with an oxygen propellant module, feed system and afterburner nozzle for "bipropellant" operation. Transition to a "reusable" mission architecture now occurs with smaller, LANTR-powered LTVs delivering either increased payloads or shorter transit times on each round trip piloted mission than is possible with "all LH_2" NTR systems. Nuclear surface power systems will also be critical to providing a good rate of return to investors in a commercial LUNOX enterprise. They provide abundant power at low mass to support continuous operation of the teleoperated surface mining vehicles, reusable LLVs, propellant production and storage units, and habitat modules even during the two-week lunar night. As the production capacity of lunar propellant increases and initial lunar outposts grow to commercially viable settlements, the LANTR concept can enable a rapid "commuter" shuttle capable of 24 hour "one-way" trips to and from the Moon. A mobile NEP tanker / propellant depot is a key infrastructure element that can provide a convenient staging point for LLO operations. It would provide Earth-supplied LH_2 to the reusable chemical LLVs ferrying LUNOX up to the depot, and LUNOX to the LANTR commuter shuttle for its return back to Earth.