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

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KEY TECHNOLOGIES, SYSTEMS, AND INFRASTRUCTURE ENABLING THE COMMERCIALIZATION AND HUMAN SETTLEMENT OF THE MOON AND CISLUNAR SPACE

Abstract

Over 50 years have passed since the movie 2001: A Space Odyssey debuted in April 1968. In the film, Dr. Heywood Floyd flies to a large artificial gravity space station orbiting Earth aboard a commercial space plane. He then embarks on a commuter flight to the Moon arriving there 25 hours later. Today, on the 50th anniversary of the Apollo 11 lunar landing, the images portrayed in 2001 still seem well beyond our capabilities. This paper examines key technologies and systems (e.g., in-situ resource utilization, fission surface power, nuclear propulsion), and supporting infrastructure elements (e.g., propellant depots), that could be developed by the private sector over the next 30 years allowing the operational capabilities presented in 2001 to be achieved, albeit on a more spartan scale. Trajectory analysis is first conducted to determine the DV requirements for a reusable lunar transportation system (LTS) operating between low Earth orbit (LEO) and low lunar equatorial and polar orbits as a function of transit time. This data is then used to size a variety of lunar transfer vehicles capable of refueling with liquid oxygen (LO2) and hydrogen (LH2) propellant supplied at depots located in LEO and strategically-positioned lunar orbits. Lunar polar ice (LPI) supplies the feedstock material to produce LO2 and LH2. On the lunar nearside, near the equator, iron oxide-rich volcanic glass beads from vast pyroclastic deposits, together with mare regolith, provide the feedstock materials to produce lunar-derived LO2 (or LUNOX) plus other important solar wind implanted volatiles, including H2 and helium-3. For short transit time flights to the Moon, the high thrust, high specific impulse nuclear thermal rocket (NTR) will be essential. Once lunar-derived LO2 and LH2 propellant production becomes established and is made available to depots in lunar orbit, a modified NTR, the LO2-augmented NTR (LANTR) is introduced into the LTS. LANTR utilizes its divergent nozzle section as an afterburner where injected oxygen supersonically combusts with the reactor-heated hydrogen emerging from the engine's sonic throat. The bipropellant LANTR engine has higher performance than a chemical rocket system, allowing short transit time crewed cargo transports and commuter shuttle flights to and from the Moon on the order of 36 hours or less. The paper provides a look ahead at what might be possible in the not too distant future, quantifies the operational characteristics of key in-space and surface technologies and systems, and provides conceptual designs for the various architectural elements discussed.