Fueling Space Colonization Using Nuclear Energy

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Mars, the fourth from the sun, was thought to be uninhabitable. With the development of reusable space architecture and other fields of study, there is a renewed interest in the colonization of Mars. One key component in solving this multifaceted issue is power generation. Nuclear energy is the best source of long term efficient dependable energy to provide electricity. Nuclear energy unlike many other sources of power is reliable and constant and can be tuned for different applications such as power generation or thrust. In comparison to solar, which has a niche on Earth, planetary conditions such as dust storms and physical distance in relation to the sun greatly decrease solar's efficacy.

Before settlements can be built on Mars material first needs to be transported, and here nuclear energy also has a potential solution with efficiencies much higher than other standard thrust methods. A system that produces thrust is a propulsion system. There is the nuclear thermal propulsion system(NTP) which is the current design choice for NASA Mars Design Reference Mission version three. Then there is the Nuclear electric thermal propulsion system(NEP). NTP's have minimal moving parts, tested hardware, and high thrust. Also compared to chemical it has a high specific impulse that is around nine-hundred. However, the NTP has limited abort scenarios in missions to Mars, high fuel temperatures, and no flown hardware. A nuclear thermal propulsion system creates thrust by using the reactor in the rocket as a heat source. The nuclear electric propulsion system takes the heat generated by the reactor and converts it into electricity through the power conversion subsystem. Any unusable heat via radiation is rejected into the heat rejection subsystem. A NEP has flight-proven hardware and flexible design. However, the heat rejection system size and the complexity of the NEP's design cause disadvantages for the system. Both the nuclear electric propulsion system and the nuclear thermal propulsion system have the same fissioning process; the NTP just does the process differently[1]. Both systems are superior options to any chemical propulsion system. The solid fuel chemical propulsion system is not restartable. The liquid fuel chemical propulsion system is complex. A cold-gas chemical propulsion system has low thrust[2]. Chemical systems are nowhere near as efficient as nuclear systems. The downside to using nuclear reactors is the radiation being emitted. This radiation is life-threatening to the crew if the reactor is not properly shielded. A space reactor shield is usually in the form of a shadow shield. Shadow shields provide the most shielding per unit of mass and the amount of shielding is minimal due to how close the shield is to the reactor[3]. As long as the reactor is properly shielded, the mission to Mars using nuclear energy will be accomplished smoothly and safely.

Mars' planetary conditions can be extremely unforgiving as temperatures can reach negative two hundred and eighty-four degrees Fahrenheit[4]. Due to the extreme cold on Mars, any power outage is potentially life-threatening to future settlements. The ozone layer on Earth protects humans from lethal amounts of solar ultraviolet radiation; Mars lacks an ozone layer, therefore, letting in solar radiation. There is still not much information on the amount of radiation that reaches the surface of Mars[5]. Dust storms during southern spring and summer encompass the entire planet[6]

A fast spectrum space reactor is best to use to provide electricity/energy to the colonizers of Mars. The main fuel to the reactor is Plutonium because its isotopes are reactive in a fast spectrum reactor which allows for a low mass and compact core design. Compared to a thermal reactor the large concentration of Plutonium produces a reduced delayed neutron production[1]. The amount of radiation in Mars's environment can provide enough neutron production for the reactor. Radiation also prevents the need for a source to start up the reactor[7]. Even with a small mass and improved fuel utilization, the reactivity transients can be too quick to control. The transients are quick because some actinides are extremely reactive in this type of reactor and the actinides have small delayed neutron yield. The transients are also quick because of the short prompt neutrons' lifetime. Under accident conditions, the core of the reactor and its control system should provide negative reactivity feedback and during normal conditions provide safe reactor operations[1]. Thermal reactors are not ideal because of their large mass and requiring moderator materials[8]. Also, its large core's lifetime reactivity is constantly changing because the fission products have high productivity worth. However, an advantage to thermal reactors is that to sustain criticality it needs a small fuel mass while in a fast reactor to sustain criticality more fuel mass is required[1]. Four to five reactors[9] built independently of one another is the best idea so if one stops working the others are not impacted.

This nuclear reactor can not be in a small area; it needs a large area so it can disperse heat[10]. Shielding is needed for the reactor. If LiH(a common shielding material) is used, it would have to be kept between 600-800K, so no swelling or embrittlement occurs. If Beryllium is used as a shielding material, it would have to be actively cooled[8]. Beryllium is successful for extended periods of time in high radiation environments[11]. Both beryllium and LiH have similar issues when being used[11].

Nuclear power sources can fit any need, application, or capacity desired. Engineers are not restricted to only building a fast spectrum reactor. Depending on the requirements engineers need to follow they can use standard liquid-cooled fission reactors, gas-cooled fission reactors, and liquid metal cooled fission reactors. Nuclear is more efficient than solar or chemical energy. Not only can it be the source of energy for colonizers but also used in the rocket as a propulsion system. When shielded properly it will not do harm to colonizers and can withstand Mars' climate. Nuclear energy is the most efficient option.

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