14th IAA SYMPOSIUM ON VISIONS AND STRATEGIES FOR THE FUTURE (D4)
Space Mineral Resources, Asteroid Mining and Lunar/Mars insitu (5)

Author: Mr. Salil Rabade
Arizona State University, United States

Mr. Nathan Barba
Arizona State University, United States
Prof. Laurence Garvie
Arizona State University, United States
Prof. Jekanthan Thangavelautham
Arizona State University, United States

THE CASE FOR SOLAR THERMAL STEAM PROPULSION SYSTEM FOR INTERPLANETARY TRAVEL: ENABLING SIMPLIFIED ISRU UTILIZING NEOS AND SMALL BODIES

Abstract

Future sustainable space exploration will require the use of off-world resources for propellant generation. Use of off-world-generated propellant will significantly increase the range and payload capacity of future missions. Near-Earth Objects (NEOs) contain a range of available resources, including water as ices and hydrated in minerals. However, water-bearing regolith would need to be excavated and the water extracted. Water is a compelling choice for fuel as it can be electrolyzed using solar photovoltaics to produce hydrogen and oxygen that is combusted to provide thrust. Our work shows Isp of 350 to 420 s can be achieved. However, this water contains impurities including carbon monoxide and sulfur that can shorten the life of high-efficiency electrolyzers. Complex processes are required to remove these impurities, which makes water extraction from NEOs challenging by electrolysis. A credible alternative to electrolysis is to simply extract water, together with impurities, and heat it into steam for propulsion. Early techniques have proposed nuclear reactors for generating heat. In this paper, we propose using solar concentrators and carbon-black nanoparticles to heat the water into steam. This solar thermal heating process converts 80 % of incoming sunlight into heat based on our laboratory tests. The process is efficient and contains no moving parts. Heat is first used to extract the water which is condensed as a liquid. Steam is then formed using solar thermal reflectors that concentrate the Sun's heat onto the nanoparticles. The heated water transfers this heat to the water using conduction. Our simulations show temperatures of up to 1500 C and Isp of 190 s can be achieved with the appropriate design of the solar thermal reflector and heat distribution system. The steam is released through a rocket nozzle that produces thrust. This approach, while not offering superior propulsion performance compared to hydrogen-oxygen combustion, is simple and robust. Steam-based propulsion is comparable to current monopropellants widely used on upper stages of interplanetary spacecrafts. This propulsion system can offer higher thrust than current electrical propulsion: there is also minimal risk as the water is inert and easily stored. We report on proof-of-concept laboratory studies that show that carbon-nanoparticle heating can convert sunlight to heat and generate steam thrust. We characterize the thrust produced and show viability of this approach using pure water, hydrated clay, and meteorites.