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NUCLEAR THERMAL PROPULSION FOR EARTH ORBIT AND INTERPLANETARY MISSIONS: CHALLENGES AND ISSUES

Abstract

From the late 1950s to date, the nuclear thermal propulsion has had the main purpose of making possible missions impossible to accomplish with chemical propulsion. The use of hydrogen as a propellant and a fuel resistant to very high temperatures, guarantees exceptional propulsive performance. A propulsion system with such capabilities has been thought of as the most suitable, since the NERVA project, to carry out missions to Mars. Even today, the literature on nuclear thermal propulsion systems appears to be full of Mars mission studies. Little attention is given to other missions potentially made accessible by this type of propulsion.

The purpose of this work is to investigate new mission scenarios that could be made accessible by nuclear propulsion and to identify the most efficient configuration of the propulsion system for each scenario. Particular attention is paid to the choice of the most suitable propellant-fuel couple for each mission.

Some mission scenarios are presented, covering both interplanetary and earth orbit missions. The specific requirements that each mission imposes on the propulsion system are determined. Particular attention is given to the determination of safety requirements, which constitute the most stringent constraints to be respected for the use of nuclear reactors in space. A literature review is carried out to identify the most promising fuels and propellants. The main chemical-physical properties of the selected fuels and propellants are presented, focusing on their mutual compatibility and the criticalities deriving from the various possible couplings. A preliminary design of propulsions system satisfying the imposed requirements for the various missions is carried out. A specific combination of fuel and propellant is considered for each configuration proposed. Different forms of the fuel and propellant paths are also taken into account. For each mission, a trade-off is made based on the performance offered by the various propulsion systems proposed. Particular attention is given to the parameter of the system specific impulse, which weighs the specific impulse on the mass of the propulsion system. This parameter is very important in systems using nuclear propulsion, where the mass of the engine occupies a large part of the total mass of the system.

From this trade-off the best nuclear thermal propulsion system configuration for each mission is determined. Finally, the possible benefits in terms of system specific impulse derived by the use of the fission reactor also for power generation purposes, in each of the best configuration, are discussed.