Human Exploration of the Solar System as a Precursor to Interstellar Travel: Outlook and Realities

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Abstract

Technical speculation about the possibilities of space travel began with Konstantin E. Tsiolkovsky at the beginning of the 20th century[1], building upon notions of rockets from centuries earlier[2]. Only with the Second World War and the competition in space between the U.S. and the Soviet Union during the ensuing Cold War were sufficient funds available to develop what has become known as astronautics to the point that robotic and human spacecraft became possible. To date, the culmination of the human program has been the Apollo landings on the Moon and the building and permanent habitation of the International Space Station (ISS). At the same time there has been a recurrent backdrop of the idea of humans traveling out from the solar system to the stars, with the topic developed somewhere between science[3] and science fiction[4], given the enormity of that task[5]. Nonetheless, it seems prudent to examine the realities and requirements of the "easier" problem of human travel throughout the solar system, to inform both the longer-term possibility of human travel beyond the asteroid belt, as well as the shorter-term goal of the human exploration of the Mars system[6]. While missions to Mars can be accomplished with chemical and/or nuclear thermal propulsion[7], continuous, low-thrust missions will be required to decrease flight times to acceptable durations for more distant targets[8,9]. For human flight the duration, living space, and expendables (food, water, and air) all become part of a significant trade space, which also reflects risk postures, both with respect to radiation tolerance and contingency strategies. In the absence of some type of induced, artificial hibernation (for which no near-term technologies currently exist) mission lifetimes will likely be limited to ~5 years. Provision of supplies, if not forward positioned, recycling efficiencies and reliabilities, living volume, and the target system all then drive the required mass and, hence, required propulsion[10]. Closure of the engineering design depends upon physical characteristics of the means of propulsion, bookkept as the specific mass of that system, which must include propulsion hardware, energy generation conversion and efficiency, and radiation of waste heat[11]. Implementation is highly dependent upon materials and system reliabilities, preplaced infrastructure, and the adopted form of nuclear energy for power and propulsion. Significant structural masses will be required for such missions with assembly in space or on Earth and/or with materials brought from Earth or mined at the Moon or Near-Earth Asteroids (NEAs). The approach taken also become part of the trade space[12]. None of these issues is new. What is new is now-available space technology, the role of even newer technologies, and the development and implementation costs, all of which we have real experience over the past five decades. In the absence of disruptive, implementable, propulsion technologies, we can visit the types of requirements that may then be needed for recurrent human Mars travel[13], and for initial human forays to the asteroid belt and the planets of our solar system beyond. The experiences of actual human expeditions throughout the solar system – not unlike the initial expeditions to Antarctica – will inform us of what the possibilities for *homo ad astra* might be when the coming century dawns[6].

Keywords: Interstellar Travel, Human Space Exploration, System Engineering

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