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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Interstellar travel is the hypothetical travel by interstellar probes or crewed spacecraft between stars or planetary systems in a galaxy. Interstellar travel would be much more difficult than interplanetary spaceflight. Whereas the distances between the planets in the Solar System are less than 30 astronomical units (AU), the distances between stars are typically hundreds of thousands of AU, and usually expressed in light-years. Because of the vastness of those distances, practical interstellar The Interstellar Probe mission would be designed to cross the solar wind termination shock and heliopause and make a significant penetration into interstellar space, thereby providing the first comprehensive in situ studies of the plasma, energetic particles, cosmic rays, fields, gas, and dust in the nearby Galaxy.Â Such an exploratory mission has been evaluated on practical scientific and engineering levels since the conference on "Missions Beyond the Solar System" held at NASA's Jet Propulsion Laboratory in 1976. 1 The socalled interstellar precursor mission, or Interstellar Probe, have continued to be discussed by individual authors, [2][3][4][5][6][7] as well as identified as a scientific priority by consensus documents in the science community. Unfortunately, the Interstellar Medium around our solar system and the nearby stars is especially thin, and scientist have calculated that thereâ€™s just not enough hydrogen there to fuel a Bussard Ramjet. "It's not the ideal part of the galaxy," Crawford said.Â And although Crawford is an advocate of human exploration of the solar system, he said that interstellar distances are too vast to make a human voyage conceivable within the next few hundred years. "I think humans can explore the planets more effectively than robots, and I also think there are cultural reasons for sending humans into space, to broaden our range of experiences and enrich human culture," he said. From solar sails to traveling through wormholes, plenty of theoretical and real-life forms of travel might eventually lead humans beyond our star.Â Scientists have long written and spoken about a perceived necessity to travel to other planets for the long-term survival of the human species. While NASA, SpaceX, and other companies have relatively short-term plans to get us to Mars, what of the need to explore beyond our star, the Sun, which is estimated to die out in 7.5 billion years? Early on, scientists planned to conduct solar system exploration in three stages: initial reconnaissance from spacecraft flying by a planet, comet, or asteroid; detailed surveillance from a spacecraft orbiting the object; and on-site research after landing on the object or, in the case of a giant gas planet, by sending a probe into its atmosphere.Â What has been learned to date confirms that Earth and the rest of the solar system formed at about the same time from the same cloud of gas and dust surrounding the Sun. The four outer giant gas planets are roughly similar in size and chemical composition , but each has a set of moons that differ widely in their characteristics, and in some ways they and their satellites resemble miniature solar systems.