# DESTINATION MARS: COLONIZATION VIA INITIAL ONE-WAY MISSIONS

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Earth is located in a dangerous part of the universe. Threats to life on Earth are manifold and range from asteroid impacts to supernova explosions and from supervolcano eruptions to human-induced disasters. If the survival of the human species is to be ensured for the long term, then life on Earth has to spread to other planetary bodies. Mars is the most Earth-like planet we currently know and is the second closest planet; further it possesses a moderate surface gravity, an atmosphere, abundant water and carbon dioxide, together with a range of essential minerals. Thus, Mars is ideally suited to be a first colonization target. Here we argue that the most practical way that this can be accomplished is via a series of initial one-way human missions.

**Keywords:** Mars, Human Mission, exploration, colonization, base station

## 1. INTRODUCTION

The 100 Year Starship Study™ initiated by the Defense Advanced Research Projects Agency (DARPA) is a project very much needed to make distant space travel practicable and feasible and represents the first major effort in this direction after a long hiatus. After the boldest step forward - the temporary human presence on the Moon with the Apollo missions - the scientific community as well as the general population is thirsting for a major challenge, for the human species to leave its cradle and start exploring the universe. Here, we argue that the first stepping stone in this endeavor should be a human colony on Mars, and provide a plan of how that could feasibly be accomplished. Further ahead, though, long duration, long distance spaceflight should be developed to also explore other planetary systems. DARPA [1] provided several lines of reasoning for why this endeavor should be pursued: (1) human survival is at stake. A dispersal of our species would provide a better chance of survival in the event of catastrophic disasters on Earth. In fact, advanced technology associated with the 100 Year Starship Study may provide the whole biosphere of Earth with a better chance of survival from a cosmic catastrophe such as a looming asteroid impact; (2) finding answers to questions that are as old as humankind: are we alone? is there other intelligent life out there?; (3) further cultural evolution of the human species through expansion of human understanding and consciousness via space exploration; (4) a general pursuit of knowledge and discovery with breakthroughs in scientific understanding; and (5) to gain a deeper sense of what we are and where we belong in the universe as part of "natural theology".

## 2. MARS AS A DESTINATION

The universe is vast and even in the immediate vicinity of our solar system (distance of less than 100 light-years) there might be hundreds of habitable planets and moons that might be suitable for exploration and possible colonization. So why should Mars be chosen as the first destination in our voyage to leave Earth? There are many good arguments for doing so.

### 2.1 Distance

Mars is the second closest planet to Earth after Venus. Using currently available propulsion technology, a journey to Mars takes about 6 months and the technology to undertake such a voyage is largely already available. There are also some other suitable targets within our region of the galaxy, such as Gliese 581d, which is at a distance of 20.3 light years. Telescopes will become even more powerful in the coming decades, especially spaceborn telescopes, and planned projects such as the Terrestrial Planet Finder will increase our knowledge many fold about the presence of potentially habitable planets in nearby planetary systems [2]. Many of these so-called exoplanets will turn out to possibly be very earth-like. The closest extra-solar planetary system, Alpha Centauri, is at a distance of 4.4 light years, with Proxima Centauri, at a distance of 4.3 light years, being the closest known star.

Thus, distances to reach habitable exoplanets are expected to be substantial. Given that the most optimistic estimates claim that 10 to 20 % of light velocity can be reached with suitable mission architecture [3], it still would take a travel time of at least one human generation to reach Alpha Centauri. The acceleration phase and deceleration phase of the journey have to be factored in and will take additional time. Further, assuming that the next habitable planet is more likely at a distance between 10 and 20 light years (Gliese 581d is at a distance of 20.3 light years), the total time required for the voyage to reach this world is more likely in the range of 100-200 years. The technology for reaching the required velocity is not at hand and has to be developed. The cost of dispatching very large payloads across interstellar space at speeds far in excess of those attainable with current technology are likely to be very many orders of magnitude greater than global scientific budgets, and look to be utterly beyond feasibility even on a

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time scale of centuries. Thus, it seems reasonable to use Mars as a first off-world base for humans, given its close proximity to Earth and being reachable with conventional propulsion technology within acceptable journey times.

### 2.2 Resources

Mars provides many of the crucial resources that are needed to establish an off-Earth human base. The most important is water, which is accessible below the Martian surface and in the polar regions [4, 5]. Humans living in a base station on Mars would mine the water for human consumption and plant cultivation in a greenhouse. By splitting the water into oxygen and hydrogen, an oxygen-rich atmosphere can be produced in the human habitation areas. This process would be powered from dependable energy sources such as nuclear fuel and solar power. Mars also provides mineral resources, which can be used as building material and soil. By enriching the Martian regolith with organic matter, it can be used to grow plants within the greenhouse. Ideally, enough food would be grown to make the human base self-sufficient over time. Establishing an enclosed biosphere on Mars would be challenging, but the sort of problems encountered in the Biosphere 2 experiments near Oracle in Arizona in the 1990s (e.g., [6]) would not be as serious a concern, since new material could be constantly supplied from the surrounding Martian environment if needed. The most important issue for eventual self-sufficiency is to provide a rich enough ecosystem with enough microbial diversity for it to be sustainable. Mars has a moderately thin atmosphere that screens out large amounts of harmful radiation (though significant protection is still required for astronauts venturing out in the Martian landscape). The moderate gravity on Mars is also an asset, since there are many medical problems that are encountered in weightlessness [7, 8].

### 2.3 Relevance to Earth Life

A human base on Mars might also provide a unique opportunity to study a second evolutionary record of life and may cast important light on the origin of life on Earth [9]. Since early Earth and early Mars had similar environmental conditions, life on Mars, if it exists, may have originated under similar conditions. Furthermore, since several studies have shown that microbial life is likely to survive the transportation from Mars to Earth and vice versa during major asteroid impacts [10-13], especially if protected well within the rock matrix of impact ejecta, there is a distinct likelihood that Earth life and Mars life may be related to each other. If so, then Martian life could represent in a sense our distant cousins, and much could be learned of how evolution shaped terrestrial life to adapt to the environmental conditions of what is now a very different planet, compared to both early Mars and Earth. Furthermore, because Mars does not have plate tectonics, ancient traces of life are likely to be better preserved than on Earth.

### 2.4 Ethical Considerations

Exploration and colonization include inherent dangers. For example, previous spacecraft that explored Mars may have already exposed the planet to a range of terrestrial micro-organisms. Direct human presence would expose the planet to a much higher load of foreign organisms. On the other hand, the danger to indigenous life from foreign organisms may be a bit overplayed. Presumably, any indigenous Martian organisms will be much better adapted to life there than will any terrestrial imports. In the case of an initial Mars colony, only a very small area of the planet would be affected by the construction of a human base, and active measures should be taken to preserve and protect any indigenous organisms, which likely consist of microbes only.

In the case of the exploration of an extra-solar planet, much greater ethical dilemmas could be encountered. For example, let us envision that the human travelers on the generation star ship would encounter a habitable planet after 100 years of voyage. What if the planet is found to be inhabited by animal-like multicellular organisms? Or more challenging, some intelligent species comparable to the Neanderthals? The prudent directive from Earth would clearly be not to intervene and potentially expose the fauna on that planet to harmful microbes that the astronauts would carry with them. We are painfully aware of the lessons from history when the Spaniards entered the Americas. Even if that analogy breaks down in view of the fact that the biochemical make-up of the alien and terrestrial life may be sufficiently different so that no actual infection occurs, it may still happen that terrestrial micro-organisms could spread unchecked on a new planet and appropriate resources needed by indigenous life would be used up. The risk is difficult to estimate. But what if the human travelers ran out of food or were in a perilous situation for some other reason and the only means of survival would be to go to that planet? No terrestrial directive or set of principles could be enforced on an expedition light years away and launched decades or centuries earlier.

Given these issues, some may argue that colonization of an already inhabited planet is altogether a bad idea, given the experiences of recent colonization episodes on Earth. However, colonization from a strictly biological viewpoint is a normal and natural part of the evolutionary process, and as such is ethically neutral. Organisms on Earth typically explore their environment and colonize new habitats and niches when available, spreading out as much as possible. Migration and expansion as biological imperatives are seen among all forms of life, including microbes, insects and mammals. Any species that doesn't follow this biological imperative is likely to be driven to extinction by the process of natural selection. Thus, if we want to survive as a species (and to some degree this also applies to other terrestrial fauna and flora), extra-terrestrial colonization is probably unavoidable over the long term. On the other hand, given that we are talking about planned and controlled extra-terrestrial colonization projects, as opposed to the haphazard nature of terrestrial colonization, we have the option to restrict it to habitable planets that do not possess any indigenous, particularly multicellular and macroscopic, life. If this directive is broken, perhaps because of an emergency situation as outlined above or because the alien life was overlooked during an initial exploration phase, everything possible should be done to preserve and protect the alien biosphere.

## 3. A SERIES OF ONE-WAY MISSIONS TO START A COLONIZATION EFFORT ON MARS

Many plans have been advanced for a human mission to Mars with a landing envisioned as early as in the 1980s, yet nothing has happened beyond the planning stage. The associated huge financial and political commitments needed to make this idea a reality seem to be insurmountable in the foreseeable future. Yet, there may be a feasible way: to start the colonization of Mars initially with a series of one-way human missions. The one-way mission as an approach to explore and colonize Mars is an idea that first surfaced within NASA during the Apollo missions. Here, we provide arguments why one-way era should be seriously considered.

### 3.1 Costs

The estimated costs for a human mission to Mars are staggering – at least in the realm of several tens of billions of dollars. However, considerable cost saving could be achieved if the astronauts did not return to Earth. Most of the savings come from eliminating the need to transport fuel for the return journey. Further, the spacecraft that is used to carry the astronauts to Mars would serve as a habitat and resource for the colonists. Costs would also be spread out by sending ahead much of the needed hardware, including the power supply (nuclear fuel cells and solar cells), habitat units, communication relays, building material for the greenhouse, a ground rover, a telescope, and various other pieces of instrumentation. The total costs for the first one-way mission and the previous robotic missions are estimated to lie between $20 billion and $25 billion. Means to pay for such an undertaking are provided elsewhere [14-15].

### 3.2 Long-Term Effort

The colonization of Mars via a series of one-way human missions would ensure a long-term commitment to space exploration and a continuous human presence on Mars. It is important to avoid the mistake of the later Apollo missions for which an appropriate long-term vision was missing. No plans were announced to establish a long-term robotic base on the Moon to be operational for a significant period of time. The cost-benefit ratio is even more unfavorable for a human mission to Mars. Would it be justifiable to mount a vastly expensive human mission with the principal objective simply being that a human had walked on Mars? Or, formulated otherwise, how much exploration would have to be included to make such a mission justifiable based on the cost-benefit ratio? A traditional two-way mission would have the astronauts staying not much longer than about a month on Mars. Given that Mars provides so many interesting sites, some of them relevant to the presence of water and possibly life, it is questionable how much the astronauts could accomplish within such a limited period of time and other mission constraints. Thus, the most logical approach would be to leave the astronauts on Mars, and entertain the vision of a permanent human base there. The astronauts would not be abandoned, but constantly supplied with further instrumentation, food, and other critical supplies, to expand the facility. Eventually other colonists would arrive. The colonists would become increasingly proficient at harvesting and utilizing local resources, eventually becoming self-sufficient and independent of the Earth supply line. New one-way missions would be launched once certain milestones in the expansion program have been reached. Eventually, the small outpost would give way to a colony, which would really begin to thrive when constant to and fro shuttle services from Earth to Mars and vice versa came to be established. Only when a successful colonization of Mars has been achieved should consideration be given for colonizing planets beyond the solar system.

### 3.3 Ethical Consideration

The astronauts who would embark on the initial series of one-way missions would be volunteers who are willing to spend the rest of their life on Mars. These are not suicide missions. Instead everything would be done from Earth to ensure that the astronauts have everything to make their life on Mars a positive and productive experience. They would be the first pioneers to live on a new world, and their prospects would not be much different than those of the first European settlers in North America. Clearly, life would not be easy for them, given the cramped and uncomfortable living conditions and the lack of sophisticated medical facilities. However, since we originally published this idea [9], more than thousand people from all layers of society contacted us and volunteered for such a mission – even though we never asked for volunteers. This demonstrates that the old human pioneering spirit embodied by the likes of Scott and Amundsen remains alive. Undoubtedly there will be risks, much higher than boarding a plane. But many adventure sports have a high risk factor, and these do not seem to be problematic for society. Many members of the armed forces and emergency services risk their lives daily, and this does not seem to be problematic either based on ethical considerations, therefore we do not consider it unacceptable on ethical grounds for a handful of adventurous and dedicated individuals to accept a modest risk of catastrophic failure, and an unavoidable reduction in overall life expectancy, for the grand goal of moving the human species forward to cross the next frontier, and to help ensure that humanity has a higher chance of long-term survival by being distributed among many planets rather than concentrated on only one.

At present, the main ethical concern related to planetary exploration concerns is the back-contamination risk – that an organism brought back from Mars, either deliberately or inadvertently as part of a return mission, might be a threat to life on Earth. (The risk is very low but nevertheless non-negligible and hard to quantify). A one-way mission, however, would remove the risk to Earth, although Martian micro-organisms might still conceivably prove problematic to the colonists. Planetary protection is a serious issue, especially if it pertains to the safety of our own planet and its extraordinary biosphere. And given the grave fallout if this assumption is wrong, upmost caution should be employed when bringing material back to Earth with (possible) alien organisms in them. One of the major tasks of the first astronauts on Mars would be to ensure that this would not happen and to obtain the insight whether Martian life (assuming it exists) might indeed pose a threat to life on Earth.

## CONCLUSIONS

If humankind is to survive for the long-term, we will eventually have to start colonizing other worlds. Within our Solar System, asteroids, the Moon and Mars are the most promising targets on which human colonization could be achieved in a reasonable time frame. Mars in particular is very suitable, because it provides many of the resources that are available on Earth and are needed for a sustained colonization effort. These resources include abundant water and carbon dioxide and a range of essential minerals. Mars is also a moderately safe environment on account of its atmosphere and reasonable surface gravity. Although surface temperatures are very low, they are not beyond the scope of current arctic exploration technology. Mars can be reached within about six months with current chemical rocket technology. It is also the most well-known planet aside from Earth, having been thoroughly surveyed to high resolution over several years, and having been studied geologically and climatologically by a variety of landers and rovers. We thus have a good knowledge of environmental conditions, which would prove crucial in selecting suitable landing and colonization sites.

Unfortunately, though technologically feasible, a Mars mission has been stuck on the drawing board due to the huge financial and political commitments needed. We propose to start the colonization of Mars initially with one-way human missions. This would cut the costs several fold but ensure at the same time a continuous commitment to the exploration of Mars in general and space in particular. The astronauts would be re-supplied on a periodic basis from Earth with basic necessities, but otherwise would be expected to become increasingly proficient at harvesting and utilizing resources available on Mars. Eventually the outpost would reach self-sufficiency, and then it could serve as a hub for a greatly expanded colonization program. The colonization of Mars would be the first step to launch the human species toward the exploration and perhaps settlement of other planets and moons, including bodies in other planetary systems.

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