

## How to use the Moon as a Testbed to Compose the Correct Crew for an Exploratory Mission to Mars

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**Introduction:** This paper contributes to the “International LunaMars Initiative” which has been presented at various scientific congresses and proposes a synergistic framework for the international exploration of the Moon and Mars. It will provide an outline of psychological and psychosocial issues that need to be addressed in order to select the most effective crew for an exploratory mission to Mars. This paper will exclusively focus on how the Moon can best be utilized as a testbed for the preparation of a crew for journeys to other planetary destinations like Mars, but will not address the human and technological preparations of human settlement on the Moon.

The current exploration roadmaps foresee that the first expeditions to Mars will have a duration of 2 ½ to 3 years and a crew of six. Such a stressful journey will have notable psychological impacts on the well-being of the crew. Once the crew arrives on Mars, there will be a communications lag of up to 20 minutes each way. Therefore, it is important that the crew members are well prepared in order to prevent or ameliorate any problems.

It is presently not feasible to effectively simulate the conditions that the crew will undergo during their trip to Mars. In order to best conduct such a simulation, the crew should be placed in a location where they are aware of their isolation, distance from Earth, and their higher risk level. The most feasible location for such a simulation is the farside of the Moon. This paper will therefore highlight why the farside of the Moon is the best location for placing the crew in an analogous environment.

**Background on the LunaMars Initiative:** The idea of the International LunaMars Initiative, which seeks to galvanize the Moon-Mars communities by providing a synergetic international framework for the exploration and development of the Moon and Mars, was initiated at the latest COSPAR assembly held in Paris in July 2004. This initiative emphasizes the independent rationales for exploration and the merits of each of both planetary bodies in the endeavor to establishing a human presence beyond Earth. It will enable the core competencies and experiences that can be most effectively applied to the exploration and development of Mars. It also shows the strong rationale to

establish a human base on the Lunar farside, after having established activities and human presence on the Lunar nearside, where many technical, psychological and extreme environmental conditions that will challenge future Mars operations can be simulated.

**Crew Selection Methods:** The composition of a crew of a certain size, which will be traveling on an exploratory mission to Mars, will be of major concern. In fact, various psychological factors which have not necessarily been taken into account in the past will be essential considerations for the selection of a crew.

At the beginning of the space age, crews were very homogeneous. They were all white males drawn from a very narrow age group, coming from the same country with pilot and engineering experience (Connors, Harrison, & Akins, 1986). Therefore NASA, for their selection procedures within this very restricted population and the short term nature of many space missions, focused on selecting out the subjects who might develop psychological or psychiatric problems in space.

In the former Soviet Union and Russia, psychological criteria have always played a major role in the cosmonaut selection process. They also started much earlier to include a more heterogeneous variety of people in their selection - Valentina Tereshkova became the first woman who flew to Space in 1963. This is not only significant because she was a woman, but also because she was the first public citizen to go into Space. Unlike the typical cosmonaut, she worked at a textile factory and was not a pilot or an engineer (Farrell, 2004). The Soviets used specific group exercises and in-depth psychological evaluations to select their fittest candidates for the various types of missions. However, more research still remains to be done on compatibility of a small group of people in an environment like space or another planetary body.

**Rationale for Lunar Base:** To prepare for future exploratory missions to Mars, the conditions to be expected are so unique and different from what is known today that it would be too risky, especially from a psychological point of view, to send an exploratory mission to Mars without addressing certain key crew selection issues. Therefore it is essential to approach the preparation for a trip to Mars through a step-by-step approach. First : Use existing knowledge from long-

duration space missions and collect further data from analogous situations on Earth or in Low Earth Orbit (LEO). Secondly : Create a human settlement on the nearside of the Moon. For many reasons including safety, the first human settlement should be on the nearside of the Moon. Unfortunately, as on the International Space Station (ISS), a lunar base on the nearside would afford a view of Earth. Third : Further isolate the crew and build the a lunar settlement on the farside of the moon. Many particular psychological conditions rely on simulating the isolation that the crew will experience on a trip to Mars. Therefore, the best and only place in the vicinity of Earth where such psychological constraints can be simulated on humans is the Moon's farside.

The Moon has scientific merit in itself to justify a human settlement, especially on the farside. A facility on the farside is will most likely conduct astronomical and geological experiments. The Moon is a natural permanent shield from the noisy Earth and a radio telescope on the Moon's farside is more sensitive to a greater portion of the spectrum (serious limitations in the HF regions for Earth or Earth orbit based instruments). An observatory on the farside of the moon can provide better observation of the very early universe with an interference-free coverage and continuous spectral ranges (W. Cochran (1998), P. Kokh (2004)). The deployment of many other observational tools and scientific experiments can also provide many advantages. For example, geological fieldwork can be conducted in the South-Pole Aitken basin (the largest known impact crater in the solar system which has the oldest unpolluted samples of the solar system). These samples, located on the exposed surface, allow the study of the Moon's lower crust and upper mantle materials and can provide clues to understanding the early solar system and its evolution.

The manning of the main base on the lunar nearside is not part of the scope of this paper. However, it is assumed that the base will evolve over time and increase in the number of inhabitants in the first few years. For the further planning of an exploratory mission to Mars, the main base will be essential for preparing long-term journeys such as a voyage to Mars. The manning of one or more small outposts of a size not exceeding six crew members (as currently envisioned for an exploratory Mars mission), situated on the Lunar farside, will be discussed below. The lunar base is an ideal location for simulating a Martian base because operationally they are very similar. Like the Moon, the crew will have a number of scientific experiments to conduct. In addition, the crew's work will be a mixture of maintenance, calibration of equipment, and geological field-work. In addition, transportation requirements can also be simulated on the Moon. The

crew can explore sites that are not located near the base, as they will have to on Mars. This will also simulate crew separation where some crew members are doing research or maintenance of the equipment, while other crew members are doing field research.

Studies should be conducted on the Moon in order to prepare and simulate planned actions on Mars. The simulation will encompass technology tests, study on physiology and adaptation of human being to partial- and micro-gravity, and psychological adaptation to very unique features of deep-space exploratory missions, as well as the simulation of various procedures and crew constraints.

**Environmental Changes:** One of the major challenges for the crew on a Mars mission will be adapting to a new and hostile environment. The extreme environment in areas like temperature, pressure, and atmosphere composition will force the crew to be dependent on a controlled environment for survival. In addition the crew will have to cope with feelings brought on by being at great distances from Earth, being in an enclosed environment for prolonged periods of time, and being faced with new and cumbersome equipment for EVAs and marswalks. All these changes cannot be fully addressed because payload mass and size restrictions. Many of these problems have already been encountered in human spaceflight to date or in ground-based simulations (e.g. submarines, Antarctic expeditions); however, all of these properties need to be simulated simultaneously in order to better understand the type of crew members that should be sent on a Mars mission. A lunar base on the farside of the Moon would be an ideal location to observe many of the effects of environmental changes on the astronauts.

One of the properties of Mars that cannot be addressed through ground-based or on-orbit research is the effects of reduced gravity. There will also be psychological effects of living on Mars, because it has one third of the gravity found on Earth. Simulating this effect that can only be found on other planetary bodies will provide very specific medical knowledge, and enhance the medical understanding of the human body. A lunar base is a necessary step to understanding how humans will react to the transition from microgravity to reduced gravity and to prolonged exposure to reduced gravity. In this sense the Moon, in coordination with the ISS, will also permit us to observe the psychological effects of gravitational changes on the astronauts. It is possible that the astronauts may arrive on Mars and need a recovery period in order to regain their muscle strength. Astronauts are very capable and very physically fit; therefore the psychological effects of temporary loss of abilities need to be better understood.

One of the hardest aspects of the Mars mission to simulate is the sense of distance. The crew will travel for 6-10 months and will be hundreds of millions of miles from Earth when they land on the surface of Mars. Once the spacecraft has been inserted on a trans-Mars injection the possibilities of aborting the mission and returning to Earth are eliminated. The orbital mechanics necessary to travel to Mars do not leave enough fuel to return to Earth once on the trajectory to Mars. For over 25 years, astronauts have orbited in LEO. LEO allows for an almost immediate return to Earth in case an evacuation of the crew is necessary. The elimination of this option will have psychological effects on the astronauts that need to be better researched and understood before a mission to Mars. A few months into the trip to Mars, Earth will be just another star outside their viewing window. This Earth-out-of-view phenomenon could have psychological side effects that negatively impact the astronaut's well-being and productivity levels.

Another issue that the long distance will exacerbate is the concern for crew member's safety. With no potential for an abort until the astronauts reach Mars there is a higher risk level in terms of mission loss or loss of an astronaut. Due to size, weight, and training constraints, crew members will have limited resources with which to resolve medical, technical or environmental emergencies. The psychological effect of this uncertainty and insecurity needs to be researched before selecting a crew for a Mars mission.

Studying crew members living on a Moon base would help answer some of the questions with respect to the astronaut reactions to distance. A base on the lunar farside would not afford the crew a view of Earth and would create an awareness of their distance from Earth. A lunar base would not have the same risk level associated with a Mars mission, but it would be a higher risk level than an LEO flight.

Space is an extremely hostile environment, therefore humans are forced to isolate themselves and live in an enclosed setting that simulates Earth environment. Due to the length and distance of a trip to Mars, the spacecraft will have to be capable of carrying all the resources necessary for the roundtrip survival of the crew. There are options that would allow some resources to be sent separately to the ship carrying the crew. In either case, astronauts are confined within a small living environment because of mass and size restrictions. A very efficient Closed Environmental Life Support System (CELSS) will be required for the trip to and from Mars. Once on Mars, it will be necessary to have systems which will ensure efficient in-situ resource utilization (ISRU) in order to provide sufficient air and food supply for the crew and also fuel for the return trip. The technical problems of the CELSS are

found in many systems on Earth and therefore can be effectively simulated on Earth. The psychological effects of confinement and isolation from a hostile environment are better simulated in orbit or on a lunar base.

The additional benefit of a lunar base is that it will also simulate excursions outside of the habitat, with the crew using space suits. Once on Mars, the crew will have to conduct outings for geologic and other scientific purposes. These outings will be exhausting and challenging because of the nature of the space suits. Although there are current proposals for skin suits and other less cumbersome suits, these technologies are not yet mature. The effects of going through a long process of putting on the space suit and then coping with loss of mobility for many consecutive hours should be studied on a lunar base before a crew is sent to Mars.

**Social Changes:** The transition from life on Earth to a journey to Mars will be a major social adaptation challenge for the crew. However, these changes can be adequately simulated on the Moon's farside. The crew will have to adapt to these social challenges, including communication delays with Earth that can lead to isolation, interacting with a diverse crew, and preparing to return to Earth. Many of the conditions that occur on a journey to Mars can be simulated in a very similar setting on a lunar base. This simulation can reproduce the psychological problems the crew will encounter.

Both, during the voyage and on Mars, the crew will experience an average of up to 40 minutes time lag in communications. This prevents the crew from having real-time communications with Mission Control or with their families. This communication barrier could create a deeper feeling of isolation. The associated psychological effects need to be researched before sending a crew to Mars.

A mission to Mars will most likely involve international cooperation. As a result, the crew will be from diverse nationalities or backgrounds. It is essential to take into account these cultural differences and a crew member's ability to adapt to working with different cultures. This problem is currently starting to be addressed for crew selection on the ISS, but the research needs to be deepened and expanded. Such research is necessary to ensure the right selection of the crew. Basic issues like hygiene and housekeeping vary greatly among cultures and are a great source of conflict. The research will have to encompass not only the character type and personality of the crew members, but also their needs and motivation, their patterns of interaction, and the cross-cultural references of each individual.

Finally, once the crew is on the long return trip back they will have to prepare to readjust to life on Earth. This could be one of the hardest psychological adjustments. It is difficult to foresee the crew's state of

mind when they begin their return voyage. It will depend on how the crew has interacted during their unique experience on Mars, on how much they regret leaving that planet after having lived there for a considerable time, and on how they expect life to be once they return to Earth. From a psychological point of view, the mission is far from over when the crew leaves Mars.

**Conclusion:** There are many challenges that the crew will encounter on the long voyage to Mars. This voyage will be stressful and dangerous, therefore it is important to select the crew that can best adapt to their harsh and changing environment. In order to develop the most effective crew selection criteria, more research needs to be done on how the crew reacts to the environmental and social changes they will encounter on a trip to Mars. A base on the lunar farside of the moon would be an ideal location to effectively simulate many of the challenges that the crew would face on a trip to Mars. The environmental issues includes crew adjustment to reduced gravity, distance from Earth, confined and enclosed environment, and exploration difficulties. The social issues include the crew adjustment to isolation, communications lag, cultural diversity, and reintegration into their communities on Earth.

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