A Case for Nature in Long-Haul Space Exploration

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Abstract

Technologically mediated nature during long-haul crewed space missions would promote the achievement of mission objectives.

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The recent uncrewed Artemis I mission, launched 16 November 2022, marked humanity's return to the active exploration of cislunar space and beyond. Over the next decade, the National Aeronautics and Space Administration (NASA) in coordination with its Canadian and European partners plans to follow this initial success with a series of crewed and increasingly long-duration flights. These missions will provide a technological testbed as well as the initial infrastructure for a permanent human presence on the Moon, followed by the first crewed mission to Mars. Specifically, the overall Artemis mission architecture calls for a sequence of increasingly complex steps that will begin with a crewed Lunar orbit, progress to the long-term human presence on the Moon, and eventually send a crewed first mission to Martian orbit [1]. The upcoming Lunar missions will require flight durations expected to increase from days to months. By comparison, the eventual first missions to Mars are forecast to last as long as 30 months; transit alone requires a minimum of six months outbound and inbound assuming optimal planetary alignment [2]. The human crews of these missions consequently will experience extended periods during which they are confined to the built environments of their orbital vehicles and surface facilities, perhaps interrupted only by the occasional extravehicular excursions.

Given the salutary effects that exposure to nature confer on cognitive performance, it would be prudent for NASA to consider some type of implementation in upcoming and especially future missions of greater length. The crews who will brave the Lunar and Martian frontiers will be required to rapidly solve a host of foreseen and unforeseen problems en

route, on orbit, and subsequent to landfall. They will be removed from nature even as they seek out new environments across the Solar System. Incorporating elements of biophilic design into the architecture of the mission could enhance cognitive functioning among the crews and thereby facilitate the success of long-haul space exploration.

Benefits of Nature

The absence of nature during long-haul space missions lasting from weeks to years could prove orthogonal to the achievement of mission objectives. For the vast majority of its history, the human species existed in close interaction with the natural world. The rise of civilization with the advent of farms, fields, and cities redolent with indoor environments is a relatively recent development, and by most accounts humanity has yet to fully adapt to modern urbanization. Conversely, there exists a robust and growing body of research demonstrating the potential for natural environments to promote human wellbeing. The potential for nature to promote cognitive functioning while simultaneously moderating the effects of anxiety is particularly relevant to missions of long-haul space exploration. Exposure to natural environments can confer benefits to psychophysiological functioning [3] and has been experimentally demonstrated to aid attention and concentration [4] while promoting emotional regulation [5]. Such exposure to nature need not entail immersion in remote natural environments, but merely facilitate a conceptual shift away from the current demands at hand. For example the availability of “urban nature” such as city parks can promote health in cities [6]. These findings matter given that extended missions in space can be problematic for physical and cognitive wellbeing [7].

The benefits of exposure to nature, and the risks inherent to its long-term absence, become potentially significant when one is limited to the confines of constructed environments such as flight vehicles, orbital stations, and even surface facilities over periods of weeks to years. The crews of the next Artemis missions to the Moon and Mars will be expected to conduct numerous complex tasks to support the mission goals. Although the current training of astronauts is notoriously rigorous and detailed to mission objectives, there will be little margin for error when missions that last weeks and present a greater parameter space of novel problems to be rapidly solved. Exposure to nature predicts positive changes in cognitive functions [8] relevant to the success of high-stress long-term missions of space exploration. The question is not whether incorporating elements of nature is relevant to mission success but of whether it could be realistically implemented within mission architecture.

Biophilic Design

NASA has advertised the Artemis mission campaign as an open architecture to allow for the incorporation of novel developments that can prove beneficial to mission success [1]. To leverage this opportunity, we propose that biophilic design be incorporated into mission architecture prior to the launch of the upcoming Artemis flights. Biophilic design incorporates a set of principles that guide the construction of physical environments by including elements of nature known or anticipated to promote affective regulation or cognitive function [9]. Incorporating elements of nature into mission design has the potential to measurably promote cognitive functioning [10] among crew members as they extend the reach

of humanity to a permanent foothold among the planets. This practice leverages the benefits of nature in a manner that does not encumber the constraints inherent to mission architecture. Plants and soil might be unrealistic to transport, but audio-visual equipment will already be present aboard crewed vehicles. We consequently recommend utilizing technologically mediated nature to augment mission architecture. There exists a robust literature demonstrating the potential for audio-visual interventions to provide meaningful exposure to elements of nature. Two sensory avenues present themselves as proverbially low-hanging fruit that could be readily incorporated into upcoming and future Artemis missions. Importantly, these elements of nature could be easily implemented on missions to the Moon, Mars, and beyond.

Humans are a predominantly visual species and research has demonstrated cognitive benefits from views of nature. For example, in a now classic study, views of nature through classroom windows promoted student learning [11]. Even exposure to nature via scenes displayed on digital monitors can confer an advantage to cognitive functioning [12]. Natural soundscapes have also been found to promote improved human functioning [13], most notably through the use of birdsong to encourage attention restoration and recovery from stress [14]. Adjuvants such as nature scenes and sounds could prove beneficial on missions of long-haul space exploration in which astronauts are confined to close quarters and removed from the environmental cues of their home planet. Such incorporation of elements of nature into space hardware requires only software that does not affect weight or space limitations, to improve human functioning within built environments. Crucially, the incorporation of technologically mediated nature into the overall Artemis mission architecture would require essentially no additional hardware. A compelling case exists for even limited exposure to elements of a natural environment to be beneficial for human functioning [15]. Moreover, the use of audio-visual equipment already onboard the current and future crewed vehicles would provide a ready set of opportunities to leverage biophilic design in support of mission success.

Someday, taking a hike on the Lunar or Martian regolith will provide future explorers ready access to nature. Until that time, given the low cost and ease of implementation, a compelling case exists for NASA to incorporate technologically mediated nature into the open architecture of upcoming Artemis missions to the Moon and Mars. If humanity is going to explore and eventually settle the Solar System, it should be able to flourish along the way so that we bring the best aspects of our species to the future we create among the planets.

Table 1. Approximate durations of upcoming Artemis missions.

Mission	Objective	Duration
Artemis I	Lunar orbit	25 days
Artemis II	Lunar orbit	10 days
Artemis III	Lunar landing	30 days
Mars Base Camp	Martian orbit	30 months

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Competing Interests

Authors declare that they have no competing interests.

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