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Integrated simulations of Mars flights on the ISS

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Abstract

The human quest towards the exploration of the solar system and beyond will likely continue to grow in the next few decades. Many scientific and technological challenges still need to be approached and solved to enable long deep space human exploration. Once answers to these challenges are available, they will be integrated in the flight plans as ad hoc operational strategies.

For the solution of specific scientific and technological problems, experiments using ground analogues may provide optimal responses; however, only the International Space Station (ISS) can play the role of *integrated* analogue, where the impact of micro-gravity, radiation, living and psychological conditions that astronauts will face during a deep space cruise, can be mimicked at the same time, in part or in whole.

Today the ISS is a unique technological and scientific platform that enables researchers from all over the world to work on innovative experiments that could not be performed anywhere else. However, it is conceivable to use the deep space analogue features of the ISS to perform integrated tests of those operational strategies needed to allow for deep space voyages, towards a potential final integrated in-space test of the entire voyage to Mars, with a fidelity as high as achievable. This utilization strategy for the ISS would help focusing research and technology on open questions for deep space exploration, also enabling further tests of the journey to Mars using other advanced platforms that will be available on Moon orbit or surface in the near future. It will also provide the ISS with the rank of "springboard" towards deep space for the general public, increasing the awareness for human space exploration. In this paper we present the ISS4Mars idea, underlining its major goals and challenges.

Keywords: ISS; Mars; Analogue; Dry run; ISS4Mars; Human Space Exploration

1. Introduction

The ISS is now proceeding towards its life end. It is the first human outpost in space with such a long record of habitability. We could categorize science performed today on the International Space Station (ISS) in two different groups: (i) science which requires the specific space environment to be studied, most often micro-gravity, without strong links to space exploration (for example crystal growth) and (ii) science and technology necessary to enable space exploration. While built as a laboratory, in a way it is perceived by the general public as the first step "towards the stars".

Many brilliant investigations performed by a large number of research teams, employing laboratories, ground based analogues as well as numerous spaceflight opportunities including the ISS, have addressed important scientific

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questions, but not necessarily provided relevant advances to those challenges whose solutions will enable human exploration. Teams involved in human space exploration have to cope with the low, non-homogeneous, speed of programs advancement: much higher in certain highly strategically oriented agency work, lower in most part of the rest of the world. One of the reasons for good research teams not to get involved in works strictly relevant to deep space human exploration, is that the need for the required solutions does not have any real deadline: the sentence "20 years from now" has been used for several decades to describe the time still needed to start a human mission to Mars. Finally, even those important solutions slowly filling the gaps of knowledge needed for a Mars exploration mission, are most often tested and validated singularly, with no attention provided to the impacts and interaction with other solutions as well as with the full set of space stressors.

The use of the ISS as a Mars flight analogue (ISS4Mars program) could maximize the effectiveness of these solutions and the efficiency of their validation and implementation. The background for this idea can be found in previous NASA work (Charles et al., 2011), investigating "*How can the ISS be used to mimic Mars missions?*" and "*How can crew increment duration be extended to 9–12 months, from the existing 6 months?*".

Performing integrated tests in the ISS, aimed at a final "dry run" of the full Mars voyage, could indeed answer many points raised above, and provide the general public with an image of the ISS fully devoted to a deep space exploration "springboard", an "ambassador" for far planets, stimulating further interest in the ISS and in the space exploration adventure. The definition of firm deadlines would allow to focus and to speed up researches enabling human exploration. Most important, ISS4Mars would provide the means to test enabling solutions, in a synergic scenario in the best available Mars voyage analogue facility.

ISS4Mars would therefore be an envelope program starting immediately with two parallel lines: (i) coordinating and pushing science and technology to fill the gaps enabling deep space exploration and (ii) provide those plans and upgrades needed to use the ISS for this unprecedented use as a Mars flight analogue. These lines would be followed by the "real" ISS4Mars project: using the ISS for integrated tests to validate solutions, till the final complete Mars voyage dry run. This envelop program is not a scientific experiment: statistics and scientific relevance are not issues at stake. It can be seen as a synergic operational validation of all the scientific and technological results applied within the frame of a human mission to Mars. A simple flow chart of this ISS4Mars strategy is presented in Fig. 1.

While focusing on the Mars voyage, this program would be relevant as well for the human missions on or around the Moon, likely to materialize in the nearer future. Many of the important gaps to be filled are indeed the same and the synergic dry run would bring benefits to the Moon voyage too. ISS4Mars could also provide suggestions about the most suitable tests to be performed in a Moon environment, on the Deep Space Habitat (DSH) or in a Lunar Base, for example. The importance of the possibility of utilizing the ISS as a testing ground for Mars exploration resulted in a special session, "The International Space Station in LEO and the Deep Space Habitat in Cis-Lunar Space as platforms for simulated Mars voyages" held at the International Astronomical Congress held in Adelaide, Australia in 2017. Finally, it would be of interest to discuss the possible synergy between this program and the future Chinese Space Station utilization.

2. Why the ISS and how to use it

The ISS provides an unrivaled number of areas where a human Mars voyage can be mimicked with a good level of confidence. Micro-gravity, radiation and habitability are the three major reasons electing the ISS as the only possible deep space integrated analogue now and probably in the next decade. Micro-gravity on the ISS is indeed indistinguishable from deep space micro-gravity. The radiation environment requires a few more considerations. Averaged dose equivalent rate on the ISS has been measured to be equal to the one on the surface of Mars (Hassler et al., 2014, Berger et al., 2016). Spectra are very similar for $Z > 1$, i.e. for the portion of the spectrum contributing the most to radiation risk. Therefore, also for radiation rate, the ISS is the best available analogue. A similar statement can be made when comparing the ISS radiation environment with the one during the travel to Mars. In this case the spectral composition is again about the same, and the dose rate differs only by a factor of about two. For the radiation environment, the ISS is thus a much more

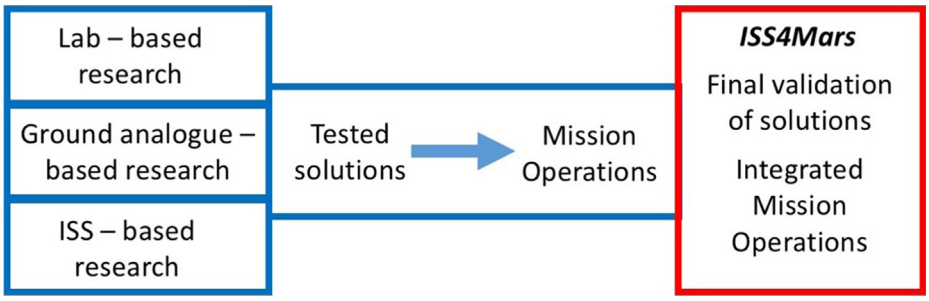

Fig. 1. Flow chart of the ISS4Mars strategy.

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