HUMAN FACTORS DESIGN FOR GEOLOGICAL/IN SITU RESOURCE EXPLORATION IN SPACE

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Introduction: In situ resource utilization on Moon, Mars and/or asteroids and comets may create a great opportunity of advantage for our future exploration beyond Earth. The high costs related to space research require increasing the success of a space mission. Considering a mission with astronauts, the relevance of the contribution of human factors design [1] is therefore discussed in this paper, for a specific case that foresees human space mission exploration for geological in situ resource utilization.

Design for Space: Astronauts work in the most extreme environments, such as radiation, adaptation to microgravity, isolation and user-system interaction, while under life-threatening conditions. These conditions are some of the many challenges that strongly affect human performance, safety and comfort, and as a consequence have a negative influence to the success of a mission. For this reason, the human factors design is particular relevant to an extreme context like space. This discipline covers the research and development for the creation of performance, safety and comfort, as elements that are strictly connected [1, 2]. The research of comfort is therefore an essential element in the investigation of all the possible factors that involve the human interaction and the success of a mission. Another important parameter, which is taken into account from the design discipline, is the interaction between the environmental constraints and the human activities.

Analogue Simulation: Terrestrial analogue studies are used to better understand the nature, the process and the utilization of geological process and resources utilization on Earth [3, 4, 5]. This understanding helps with the interpretation and validation of information from orbiting or surface missions on extraterrestrial bodiesIn this analogue context, the nature of the geological analysis is simulated within the human-factors procedures. The human factors design discipline aims to guarantee the safety, performance and comfort as explained [1, 2, 6].

The Mars Desert Research Station (MDRS) is an analogue site, where human space mission simulations are performed. During the simulations, all the possible factors that interact are investigated, such as human factors and geological/in situ resource exploration [7, 8]. Every two weeks an exchange of crew takes place. The crew consists of six members, who arrive at the station to perform a new mission. They establish the knowledge and equipment necessary for future planetary exploration, which is also viewed from a human factors perspective [2, 9, 10, 11]. The aim of geological fieldwork simulations at analogue terrains is to determine what is necessary in terms of knowledge and equipment for planning a successful mission and performing planetary geological fieldwork efficiently [9, 12].

A specific investigation was performed at the MDRS, in the frame of ILEWG EuroMoonMars campaign [3], with the purpose to increase mission success, and the main focus on the specific field of geological/in situ resource utilization. The specific geological set-up around the station is a good simulation of the Mars environment, since the station is located in the San Rafael Swell nature reserve, a red-colored desert in Utah (*Image 1*) [13].

Image 1: Geological EVA, MDRS (© Schlacht 2010).

Application: In order to test geological procedures, two crewmembers performed geological/in situ resource exploration. A geologist based at the MDRS guided them. The goal was to verify the presence of life forms, such as fossils, and take their samples. After several kilometres and three hours of exploration, the crewmembers decided to go back to the MDRS. "*Looking for something that you are not sure even exists may increase the stress and the difficulty of the task*", reported one of the crewmembers. On their way back, the shape of an old river appeared. They needed to make a quick decision, because the fuel and oxygen levels were low, and decided quickly to discard the re-entry plan, in order to start analysing the site with cameras and geology field instruments. After a few minutes, the two crewmembers detected shell fossils and sampled them. Sketches and a description of the location were made. The exploration ended successfully with the discovery of life on Mars!

The crewmembers reported that the main difficulty was the use of the instruments. For example, the monitor of one of the instruments was not readable through the specific light conditions and the filter generated by the helmet. Another example was that the keyboard of another instrument could not be used with gloves (*Image 1*). The interaction with these instruments slowed down the time needed for the activities, considering the fuel and oxygen constrains. This resulted in increasing the stress and decreasing the performance.

The MDRS mission resulted in detailed geological sampling procedure flowcharts and mission guidelines from design and geological approach (*Table 1; Schema 1*). Some extremely relevant result were reported [1, 9, 12]:

- Making new discoveries involve facing unexpected problems. Crewmembers need to be creative and qualified to make quick decisions to solve those problems.
- The design of field training and adapted fieldwork instruments and tools are essential to optimize the exploration of in situ geological resource exploration

These statements confirm the relevance of a sound design based on the comfort of the crewmembers, in order to achieve the maximum performance and results.

Conclusion: In order to perform fieldwork efficiently during planetary missions and establish the knowledge and equipment necessary for future successful planetary explorations, the contribution of human design is fundamental for three reasons:

(1) To create the necessary conditions needed for operating in space missions with astronauts;

(2) To understand the environmental constraints of the confined environment in these kind of projects;

(3) To the research of comfort necessary to optimize the safety and human performance therein.

Schema 1: Results of geological mission simulation at MDRS: Procedure [9,12,14]

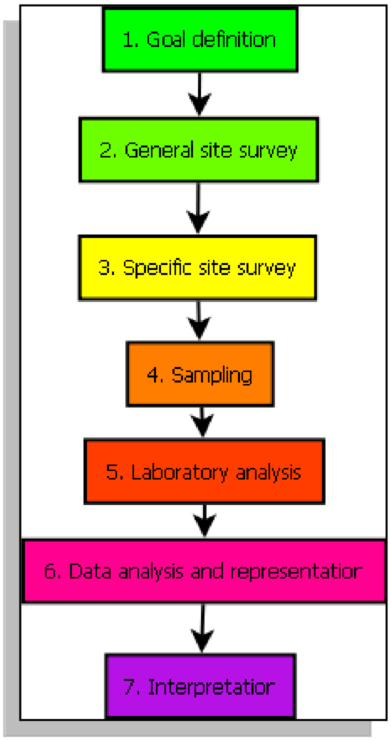

Table1: Results of geological mission simulation at MDRS: Geological Guideline [9,12,14]

GEOLOGICAL GUIDELINE
• **Crew expedition may foresee discovery that cannot be seen on aerial photo.**
• **Making new discoveries involve facing unexpected problems, crewmembers need to be creative and qualified to make quick decisions to solve these problems.**
• **Field documentation (image, audio recording, sketches, sampling labelling and location identification, scale reference and the indication of the direction of view) is extremely relevant, the tools must be dedicate and adapted to human interaction in EVA suits.**
• **Important things to consider for real missions are the effects of space weathering on the rocks, the interaction of certain materials with electronics and temperature differences, and the effect of rock splinters from hammering on the spacesuit**
• **Field geological communication must be trained.**

Thanks: Mars Society, ILEWG (*sci.esa.int/**ilewg**/*), Politecnico di Milano, www.Extreme-Design.eu. For the invitation: Planetary & Terrestrial Mining Sciences Symposium (PTMSS) &Space Resources Roundtable (SRR)

References:

[1] **Schlacht, I.L. (2012).** SPACE HABITABILITY: Integrating Human Factors into the Design Process to Enhance Habitability in Long Duration Mission. Doctoral Dissertation, Technische Universität Berlin, Germany. Published from the TU-Berlin. http://opus.kobv.de/tuberlin/volltexte/2012/3407/

[2] **Schlacht, I.L., Roetting, M., Masali, M., & Micheletti Cremasco, M. (2009).** Human Factors in Space Mission. In: Lichtenstein, A., Stößl, C., & Clemens, C. (Ed.). Der Mensch im Mittelpunkt technischer Systeme. Proceeding of 8. Berliner Werkstatt Mensch-Maschine-Systeme, 7-8.10.2009, Berlin, Germany. Düsseldorf: VDI-Verlag. ISBN: 978-3-18-302922-8

[3] **Foing B. et al., (2011).** Field astrobiology research in Moon–Mars analogue environments: instruments and methods. International Journal of Astrobiology 10 (3): 141–160 (2011), Cambridge University Press http://journals.cambridge.org/action/displayFulltext?type=1&pdftype=1&fid=8286804&jid=IJA&volumeId=10&issueId=03&aid=8286802

[4] **Foing, B. et al (2010).** ILEWG ExoGeoLab & ExoHab Team: ExoHab Pilot Project & Field Tests for Moon-Mars Human Laboratories , http://adsabs.harvard.edu/abs/2010EGUGA..1213688

[5] **Foing, B. H., Stoker, C., Ehrenfreund, P., Editors (2011).** Astrobiology field research in Moon/Mars analogue environments Int J Astrobiology, 10, special issue 03, pp. 137-305 and references therein http://journals.cambridge.org/action/displayIssue?jid=IJA&volumeId=10&seriesId=0&issueId=03

[6] **Schlacht, I.L., Hendrikse, J., Hunter, J., Karga, V., Mangeot, A., Ono, A., Rai, B., Ferreira, I., Benchenafi, R., Foing, B. (2012).** MDRS 2012 ILEWG campaign: Testing habitability and performance at an analogue moon base infrastructure outpost on earth. IAC-12.A5.1.2. IAC2012 1-5/10/2012. Napoli: Italy www.iafastro.net/download/congress/IAC-12/DVD/full/IAC-12/A5/1/manuscripts/IAC-12,A5,1,2,x14231.pdf

[7] **Schlacht, I.L., Voûte, S., Irwin, S., Mikolajczak, M., Foing, B., Westenberg, A., Stoker, C., Masali, M., Rötting, M., Crew 91 & Mission Support (2010).** Moon-Mars Analogue Mission at the MDRS. EuroMoonMars-1 Mission. IAC GLUC Global Lunar Conference 2010 (Beijing).

[8] **Hendrikse, J., Ono, A., Schlacht, I.L., Ferreira, I., Rai, B., Benchenafi, R., Theatre, K., Lan San, A., Bourges, Q., Ansart, M., Dompnier, R., Foing, B. (2011)** Human and Robotic Partnerships from Euro-MoonMars Analogue Missions 2011. IAC-11.A5.3.-B3.6.8 IAC2011, Cape Town, SA. www.iafastro.net/download/congress/IAC-11/DVD/full/IAC-11/A5/3.-B3.6/manuscripts/IAC-11,A5,3.-B3.6,8,x11248.pdf

[9] **Voûte, S. (2010).** Testing planetary geological sampling procedures in a Mars analogue site. 38th COSPAR Scientific Assembly, 18 – 25 July 2010, Bremen, Germany.

[10] **Hendrikse, J., Theatre, k., Lan San, A., Benchenafi, R., Bourges, Q., Ansart, M., Dompnier, R., Ono, A., Schlacht, I.L., Ferreira, I., Rai, B., Foing, B. (2012).** Human Robotic Partnerships: experience from terrestrial analogues campaigns. GLEX-2012,04,P,5.p1,x12685. Global Space Exploration Conference 2012 (GLEX). 22-24 May 2012 Washington, DC, USA

[11] **Mangeot, A., Hendrikse, J., Schlacht, I.L., Ono, A., Rai, B., Poos, W., Zhao, W., Rammos, I., Rodrigues, L. (2012).** Human-Robotic Partnerships and Performance: Lessons Learned From ILEWG Euro-moonmars Campaigns 2012 and 2011. IAC-12.A5.3-B3.6.2. IAC2012 1-5/10/2012 Napoli: Italy. www.iafastro.net/download/congress/IAC-12/DVD/full/IAC-12/A5/3-B3.6/manuscripts/IAC-12,A5,3-B3.6,2,x15802.pdf

[12] **Voûte, S. (2010).** Geological Space Exploration: Testing sampling procedures in space analogue environment. IAC GLUC 2010 Congress (Beijing).

[13] **Mars Society (2014).** Mars Desert Research Station. Published by Mars Society. http://desert.marssociety.org/home/about-mdrs

[14] **Voûte, S. (2011).** How the world gains understanding of a planet: An Analysis of Scientific Understanding in Earth Sciences and of the Communication of Earth-Scientific Explanation. Utrecht University (The Netherlands). http://dspace.library.uu.nl/handle/1874/198552