EXPLORATION SIMULATIONS ON EARTH

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ABSTRACT

Before every complex operation involving numerous hardwares, people and procedures, simulations are conducted in order to achieve the best level of preparation. Planetary exploration will be a complex and demanding operation. Thus simulations are conducted by different agencies and organizations on Earth to prepare this new step in human space exploration. Most simulations are focusing on field operations because the previous simulated field operations, in the frame of the Apollo lunar program, are now 50 years old. This paper gives an overview of these simulations and of some of the experiment which are conducted.

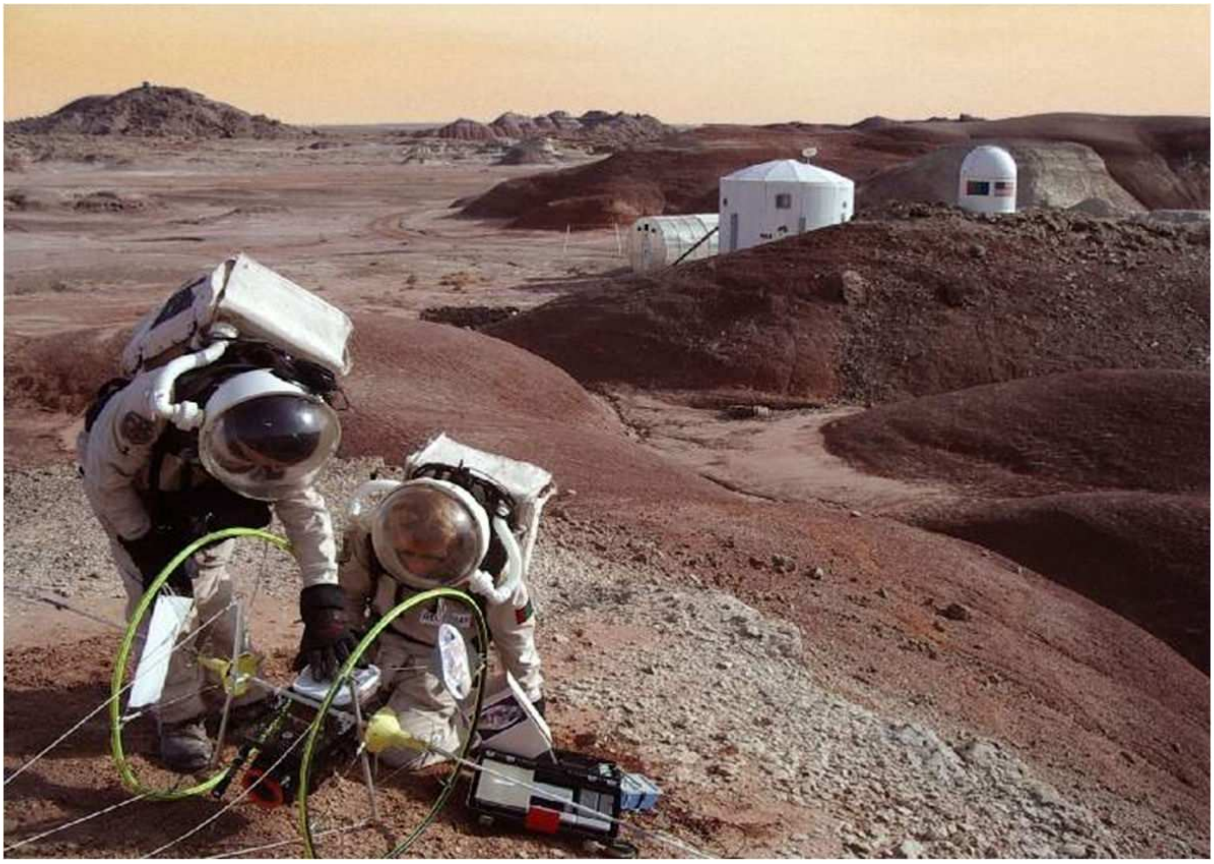
1 INTRODUCTION

Presently only robotic probes and vehicles are operating in the solar system, and, on the ground, on Mars. But human exploration will one day boost the exploration capabilities and the science return in planetary science and life research, and will push the development of new technologies in the field of energy sources and management, recycling and resources wise utilization, robotics to human interfaces ergonomics. Also it will be a powerful means of promoting international cooperation and also companies and laboratories networking. It will also be a wonderful tool to promote sciences and technologies among students.

2 SIMULATION OBJECTIVES

Before the Apollo trips to the moon, the astronauts were trained on the field (on Earth) to geology, collection of samples and all the operations they will have to perform on the moon as deploying instruments or piloting a lunar rover. Also in the sixties, a habitable rover (which would be on an alien world a pressurized rover) was designed and tested on the field.

In 2000 the US Mars Society implemented a simulated Mars habitat on Devon Island in northern Canada, on the Nunavut territory and in 2002 another one in southern Utah. These habitats were probably the first of their kind, devoted to simulate astronauts operations on another planet, mainly in this case Mars. The habitat was designed to be similar to a Mars habitat, launched by a heavy launcher which upper stage would have an 8 to 10 m diameter. The Mars society habitats are 8.3 m in diameter, and have two floors. They are designed for a crew of 6. Operations outside, called EVAs for ExtraVehicular Activities are conducted in simulated or analog spacesuits. This suits which are unpressurized for difficulty and safety reasons, have for main objective to recreate the difficulties to execute operations outside which would be experienced by an actual astronaut. Being unpressurized, they are also lighter than a true spacesuit. Under one g on Earth, the astronaut in simulation may experience around the same weight as under 0.38 g on Mars with a bulky spacesuit (but his inertia remains smaller).



Outside operations have to be conducted in simulated spacesuits which are more or less sophisticated (doc. APM)

The operation outside are science and exploration oriented. Geology and biology (for example searching in the desert areas for extremophiles living under stones or inside stones) are among the topics. These operations are conducted more slowly and with more difficulties than would be the case without spacesuit. Operations are necessarily more prepared in advance. Ordinary tools have to be adapted. Other operations are more technology oriented such as conceiving and using rovers, defining and using cameras (high definition panoramas, distances information on the picture, elevated cameras on poles or balloons) or vehicle able to send instruments along a cliff. The French association Planète Mars has thus designed and experimented different versions of a manual cliff rover since 2002, the first objective being to demonstrate an all terrain vehicle for vertical or stiff slopes. Insuring communications and localization on the field without availability of a GPS is also among the technological objectives.

Inside the simulation habitat experimentation are conducted on health, psychology, stress, relations between crew members, food, bacteria growing. The habitat layout itself is an experimentation subject: how to optimize room, avoid perturbations between areas (noise, crew circulation,…). Dedicated habitat technologies may be tested as water recycling, information system, power sources. The simulation habitats have not been so far pressurized nor had an air life support system.

But simulation objectives are also organization or systems oriented with the following questions.

-On the planet: how rovers may interact with humans; what help to the explorers may bring different devices, computers and software; what information and measurements are to be relayed towards the base; how is organized safety during EVAs, what are the emergency means and procedures; how you maximize exploration and discoveries on the field; how do you combine different thematic (geology, biology, technology) on the field and use the crew expertise in various domains.

-Between the planet and the Earth and on the Earth: what information and measurements are to be relayed towards the Earth; what is the share of data post processing between the planetary base and the Earth; how do you organize the mission support when crews have more autonomy than during spaceflights close to Earth and are separated from Earth by time delays between 3 and 20 mn; what scientific feedback Earth provides to the crew in order to adjust the following days or months of operation.

Today the simulations are oriented towards all these objectives preparing actual exploration. Tomorrow the simulations may be oriented towards crew preparation and selection.

And it is necessary to take into account that simulations are only simulations. So the similarity and dissimilarities between the simulations and the actual planetary conditions have to be listed in order to validate the results.

3 OVERVIEW OF SIMULATIONS CONDUCTED IN THE WORLD

This chapter is only an overview which may be far from complete. It has been written either from information publicly available or by the author own experience in some of the simulations.

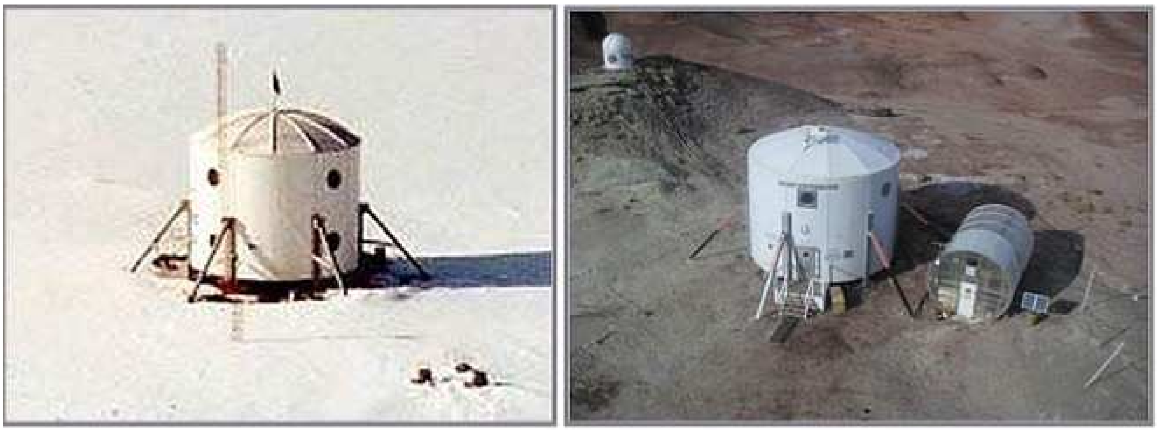
The US Mars Society has started operating the FMARS simulation habitat on Devon Island in the Nunavut territory of Canada mid 2000. The area is an old meteoritic crater (Haughton) with ice underground (permafrost) which bears evident similarities to the Mars terrain. Initial simulation operations were started in 1997 on this site by Pascal Lee from NASA Ames. They are still going on, managed by Lee co-founded Mars Institute.

The MDRS second habitat, similar to FMARS started its operations in 2002 in Utah on an old sedimentary seabed from the secondary era. There also similarities with Mars terrains are highly probable.

Crews are occupying the FMARS facility in general only in July for climatic reasons, the station being located at 75°25' N. In Utah, on the opposite, the station is not occupied from mid spring to mid autumn, the climate being too hot.

Apart from a 120 days mission in FMARS in 2007, the stays duration in these stations are two weeks, and the crew size is 6.

Beginning of December 2012 the crew n°119 is occupying the MDRS station



The Mars Society habitats in Devon Island and in Utah (doc. APM/TMS)

NASA has initiated field planetary exploration simulations in 1997. Designated Desert RATS (Research And Technology Studies), these simulations are mostly conducted in Arizona or California deserts. They involve space suits, habitat robots and vehicles including what would be on the moon or Mars pressurized rovers. The pressurized rovers were tested starting in 2008. Although small habitats were already present on the field before, the first representative habitat was used in 2010. Focused first on Moon or Mars exploration simulations, the activities were reoriented towards asteroid exploration when this objective became the NASA beyond low earth orbit first objective. During the 2011 RATS campaign, ESA operated a science mission room at ESTEC.

NASA has also initiated in 2008 In Situ Resources Production demonstrations in Hawaï on volcanic terrains. The aim is to extract water and oxygen from the ground.

In 1993 the NOAA has installed an underwater habitat designated Aquarius at a depth of 18 m along the Florida Keys Islands. NASA is using this laboratory for exploration simulations. The quasi zero g conditions prevailing under sea are suitable for asteroid type exploration. The NASA program is called NEEMO for Nasa Extreme Environment Mission Operations. In 2012, the 16th campaign involved an ESA astronaut Tim Peake.

Habitats used by NASA on ground and under water (doc. NASA)

ESA is organizing campaigns in extreme or particular environments like CAVES in 2012. CAVES stands for Cooperative Adventure for Valuing and Exercising human behavior and performance Skills. As the acronym indicates, the operations were conducted in a cave in Sardinia (Sa Grutta caves) during six days with an international crew of astronauts. A similar operation was already conducted in 2011.

Since 2008, ESA is sending a medical researcher to the French Italian Concordia base in Antarctica. This base is operated by the French polar institute IPEV and by the Italian PNRA. Concordia is not intended to simulate a planetary base but its particular isolated location and conditions of operations bear similarities to such a base and experiments related to a planetary habitat and exploration may be conducted there. Since 2005 Concordia has been equipped with the ESA MELiSSA (Micro- Ecological Life Support System Alternative) system for water treatment.

The Mars 500 operation has been widely publicized. This simulation was conducted by the Russian Academy of Sciences Institute of Biomedical Problems (IBMP) in Moscow. Three different international crews of 6 volunteers were involved in three successive operations lasting 15 days (shake up test in 2007), 105 days (2009) and finally 520 days (2010-2011). During these operations the crew was confined in different compartments simulating the Mars transfer habitat and the Mars excursion module. EVAs were conducted on a Mars simulated field. The objectives focused mostly on health, biology and psychology. ESA was part of the program with 2 volunteers for each of the long missions. The IBMP has organized numerous smaller confinement simulations in the preceding years.

The Concordia IPEV-PNRA base in Antarctic and the IBMP Mars 500 installation in Moscow (doc ESA/Alex Salam – doc. ESA)

The Austrian Space Forum (ÖWF) conducted a simulation In Rio Tinto in Spain in April 2011 involving 10 nations and ESA. The ÖWF has developed a sophisticated simulation spacesuit called Aouda, with pressure effects restitution, biomedical transmission and advanced man machine interface. The spacesuit features characteristics allowing research on planetary protection. Activities are conducted in the frame of the PolAres interdisciplinary program. In the Austrian Dachstein ice caves, a second large scale simulation occurred in April 2012. Underground ice is existing on Mars and is a good location to search for life signs. The operations involved 12 experiments from 10 nations. In February 2013 a one month simulation is planned in the Erfoud area in Morocco.

The sophisticated ÖWF Aouda X analog spacesuit in the Dachstein ice cave during an experiment on samples contamination (doc. ÖWF (Katja Zanella Kux))

4 EXPERIMENTATIONS PARTIAL OVERVIEW

After participating in the Mars Society MDRS habitat simulations in 2002 and 2006, the author conducted at the end of 2007 a survey on the experiments conducted in the MDRS habitat and on the field around, since the beginning of operations in 2002. 191 experiments were identified. They were arbitrarily separated in six categories and the percentage of activities per domain is indicated in the following lines:

- Human factors/psychology/ergonomics 23%
- Geology 28%
- Biology 13%
- Technology 19%
- Exploration methodology 15%
- Atmosphere 2%

Some experiments could be considered as being in two categories. For example, searching for endoliths living inside stones is a mixture of geology and biology. But each experiment has been affected only to one category. Also experiments conducted on more than one rotation are taken for only one experiment.

A survey has also been conducted on the arctic FMARS base experiment but only on the long 120 days 2007 operation. 21 experiments were identified with the following statistics:

- Human factors/psychology/ergonomics 24%
- Geology 33%
- Biology 24%
- Technology 5%
- Exploration methodology 14%

It is interesting to note that the FMARS 120 days operation being conducted in summer in a North polar region, daylight was permanent. This allowed 37 days during the mission which were conducted on Martian time with a day of 24h 40mn without the perturbation of conducting EVAs at night.

To illustrate the categories, the experiments conducted during the MDRS 43 simulation in 2006 in MDRS with the author participation are listed below:

- Cliff Reconnaissance vehicle	Technology
- Dexterity improvements on gloves	Technology
- Camera on pole	Technology
- Camera under balloon	Technology
- Measure of area observed in EVA	Exploration methodology
- Observation capability in EVA	Human factors/psychology/ergonomics
- Habitat lay out	Human factors/psychology/ergonomics
- Psychological assessment	Human factors/psychology/ergonomics
- Crew type of activities statistics	Human factors/psychology/ergonomics

Other examples of experiments are to be found in the following table concerning the Dachstein ice cave simulation.

Experiment	Organisation	Beschreibung
Aouda.X Spacesuit Simulator	Austrian Space Forum	Suit-subsystems check-out, field test of telemetry receiving station – subsystem commissioning & voice recognition
A.X MAT/EP	Medical Univ. of Innsbruck	Medical monitoring tool – continuation of the Rio Tinto 2011 medical survey protocol
PRoVisG Cave 3D Rekonstruction	Joanneum Research, Austria	3d TOF-camera for surveying parts of the cave with a high-resolution SLR camera
EXOMARS/WISDOM	LATMOS/IPSL, France	Ground validation for the ESA EXOMARS georadar under varying terrains
Asset planning	Univ. of Innsbruck, Austria	Field testing of a planning algorithm for traverse, consumables and hardware planning
CRV / Cliffbot	Association Planète Mars, France	Concept rover for studying steep terrain and cliffs
Terbium luminescence assay (µEVA)	NASA/Jet Propulsion Lab	Studying contamination vectors and germination rates of water/soil samples within the cave
Asimov Jr. R3	Part Time Scientists (Google Lunar X-Prize)	Chassis and drive-train tests for the GLXP lunar rover prototype
MAGMA 2	Polish Mars Society	Operational tests and demonstration of the winning rover of the University Rover Challenge
Life in Surface Ice (LISI) - Leben im Oberflächeneis	Vrije Universiteit Amsterdam, Netherlands	sterile collection of samples for PCR and phylogenetic analysis
Antipodes	Kiwispace, New Zealand	Simulation of a two-landing teams on Mars scenario – command handover for a remote science experiment
ERAS C3 Simulator	Mars Society Italy	A Mars-analog Command, Control and Communication (C3) infrastructure providing processing and communications capabilities

Experiment conducted during the Dachstein ice cave campaign (doc. ÖWF)

The Planète Mars association Cliff Reconnaissance Vehicle operated by the ÖWF suit tester in the Aouda X spacesuit in the Dachstein ice cave (doc. ÖWF/APM)

5 CONCLUSIONS

Since around 10 years many simulations concerning planetary future exploration by astronauts have started. Some are based on fixed installations representing a planetary habitat, others are located on temporary field of operation, which allow for a large variety of terrains to test procedures, hardware and organizations as well as human beings. Both approaches are interesting. These simulations will be probably extended in the future till the point they will become training for future exploration crews. It should be noticed that Europe has no permanent facility for such simulations. The implementation of such a facility and its operation are not expensive in the referential of space programs and missions. Many organizations are interested and the appeal to public and outreach efficiency is enormous.