
Isolated and Confined Environments

Carole Tafforin

Ethospace, Toulouse, France

Characteristics of space analogue environments with regard to human performance concern the crew adaptation in a socio-psychological context and in a temporal dynamics. Isolation, confinement and time are major features on Earth to reproduce an extra-terrestrial environment for manned mission simulations. In the current space missions (low Earth orbit, LEO) and in the perspective of interplanetary missions (near-Earth asteroid, Moon, Mars), men and women will have to adapt to social constraints (crew size, multinationality, mixed-gender) and spatial restrictions (volume, multi-chambers, life-support) on short-term, medium-term and long-term durations. The crewmembers also will have to perform intra-vehicular activities (IVA) and extra-vehicular activities (EVA). For training, preventing and optimizing such tasks, simulations of living and working together in isolated and confined environments, and simulations of operating with a space suit on geological surfaces are the new requirements.

During the two decades (1991–2011), space simulators (confinement) and analogue settings (isolation) were adequately developed on Earth with the ultimate goal of walking on Mars. Time periods extended up to 500 days. Space analogue environments are located worldwide (Canada, United States, Russia, Europe, Antarctica and Arctic). Mission durations in space analogue environments cover days, weeks and years. Isolation and confinement facilities implemented for such simulations are listed in Table 17.1.

Over a 7-day duration, the Canadian Astronaut Program Space Unit Life Simulation (CAPSULS) was an Earth-based initiative that simulated a typical space shuttle or space station mission [1]. CAPSULS provided the Canadian astronaut participants with space mission training. The facility was a solid

Table 17.1 Isolation and confinement facilities implemented for such simulations

Name	Type	Site	Year	Crew			Duration
				Size	Nationality	Gender	
ISEMSI	Multi-chamber	Bergen, Norway	1990	6	European	Males	118 m ³ 28 days
EXEMSI	Multi-chamber	Cologne, Germany	1992	4	European	Males	95 m ³ 60 days
HUBES	Multi-chamber	Moscow, Russia	1994	3	Russian	Males	100 m ³ 135 days
BIOSPHERE 2	Desert station	Arizona, USA	1991	8	Multi-	Mixed	1.27 ha 730 days
CAPSULES	Hyperbaric chamber	Toronto, Canada	1994	7	Multi-	Mixed	(surface) 6 months
SFINCSS	Multi-chamber	Moscow, Russia	1999-2000	33×2	Russian	Males	100 m ³ 240 days
FMARS	Polar station	Devon Is. Canada	2000-2007	6-7	Multi-	Mixed	416 m ³ 7 days-4 months
NEEMO	Undersea missions	Florida, USA	2001-2004	6-9	American	Mixed	401 m ³ 6-12 days
MDRS	Desert station	Utah, USA	2002	6-8	Multi-	Mixed	500 m ³ 15 days
CONCORDIA	Polar station	Dome C, Antarctic	2006-	10	French, Italian	Mixed	1,500 m ² 8 months
TARA	Polar ship	Ice pack, Arctic	2008	10	Multi-	Mixed	36 m 507 days
MARS-500	Multi-chamber	Moscow, Russia	2010-2011	6	Multi-	Males	550 m ³ 520 days

steel hyperbaric chamber that was comprised of two primary modules, the habitat module and the experiment module, which were connected by a smaller transfer chamber. During the simulation, crew inside monitored and controlled life-support parameters (temperature, humidity, pressure of oxygen, carbon dioxide, nitrogen and water vapor). CAPSULS involved national (Canadian) mixed-gender and small-size crew for short-term simulations. They emphasized social and personality issues of adaptation.

Over a 6- to 12-day duration, NASA Extreme Environment Mission Operations (NEEMO) project was an analogue mission that sent groups of astronauts, engineers and scientists to live in Aquarius, the world's only undersea research station [2]. The Aquarius habitat and its surroundings provide a hostile environment with the risk of decompression sickness in depth immersion. NEEMO crewmembers, named Aquanauts, experienced some of the same challenges that they would on a distant asteroid or on Moon. During NEEMO missions, the aquanauts simulated living on a spacecraft and tested spacewalk techniques. Crew size was equivalent to a real space crew. Like CAPSULS, there were mainly national (USA) but mixed-gender crew and for short-term simulations. Underwater condition had the additional benefit to simulate a microgravity environment by buoyancy. The peculiarity



Figure 17.1 Tara expedition in Arctic (Image © F. Latreille/Tara expédition).

of NEEMO is that crewmembers participated in undersea sessions of EVA and used autonomous life-support systems during IVA (Kanas et al. 2010).

Over a 15-day duration, Mars Research Desert Station (MDRS) was one of four stations planned by the International Mars Society [3] which has established a number of prototype Mars Habitat Units around the world. MDRS is a 2-deck facility providing a comprehensive living and working environment for a Mars or Moon crew. The upper deck includes sleeping quarters, a communal living area, a small galley, exercise area and hygiene facilities with closed-circle water purification. The lower deck includes the primary working space for the crew: small laboratory areas for carrying out geology and life science research, storage space for samples, airlocks for reaching the surface of planets, and a suiting-up area where crewmembers prepare for surface operations. MDRS also involved small-size but multinational and mixed-gender crews, for longer-term simulations. They thus emphasized cultural issues. The specificity is EVA while walking in a desert landscape mimicking a Mars landscape.

Over a 28-day duration, Isolation Study for the European Manned Space Infrastructure (ISEMSI) was one of three European campaigns implemented as precursor flights regarding medium-term orbital stays [4]. ISEMSI was a confined habitat in multi-chamber facilities composed of 6 modules. Two small modules served as sleeping chambers, the larger module served as working and living chamber, one module was used as sanitary, one module acted as a transfer lock and storage and one module was a rescue chamber fully equipped to maintain life-support functions under pressure. As in NEEMO and MDRS, the crew size was as expected for space mission and space exploration but



Figure 17.2 Concordia station in Antarctica (Image © IPEV).

with only male crewmembers. ISEMSI campaign was specifically designed for psychological and physiological issues on long-duration manned space mission.

Over a 60-day duration, Experimental Campaign for the European Manned Space Infrastructure (EXEMSI) prolonged ISEMSI campaign, thus doubling the time spent in a confined habitat. The overall facility consisted of two main modules serving respectively as the habitat and the laboratory module for carrying out scientific investigations and teleoperations, completed with two transfer and storage modules [5]. The living quarters containing bunks and a table were used for sleeping, eating and leisure time. In the panel of confined and isolated settings, ISEMSI had the smallest volume and the smallest crew size. It differed from NEEMO and MDRS because it provided only IVA but promoted further advances on long-duration manned space mission.

Over a 135-day duration, Human Behavior in Extended Spaceflight (HUBES) prolonged ISEMSI and EXEMSI campaigns and was definitely considered as a space simulator for extended periods [6]. The confined habitat was designed as a unique module, thus sharing living area, working area and storage area in a small volume compared to CAPSULS. HUBES had the benefit to reproduce real mission aboard the Mir orbital station and crew transfer flight considering the very small crew size consisting of Russian and male-only crewmembers. HUBES was a ground-based simulation aimed at comparing and validating psychological issues in crew selection, training, monitoring and in-orbit support flight.

Over a 4-month duration, Flashline Mars Arctic Research Station (FMARS) hosted a long-duration mission that quadrupled the in situ simulation of both confinement and isolation. Its geographic location, the polar



Figure 17.3 Mars Desert Research Station in Utah/USA (Image © Ethospace).

desert, is the largest uninhabited island in the world [7]. The 24-h daylight is analogous to that of a polar Moon or Mars mission. FMARS and MDRS have the same Mars Habitat Unit. The difference is the simulation of Mars-Earth latency to a 20-min delay and the tightly life-support since water use was restricted and monitored. However, the facility was not hermetically locked as enforced during NEEMO mission. Important analogue features of FMARS were EVAs and the hostile surroundings in Arctic. The multinational and mixed-gender composition of the crew properly simulated future isolated and confined crews who would land on asteroids, Moon or Mars.

Over a 110 to 240-day duration, Simulation for Flight of International Crew on Space Station (SFINCSS) was devoted to determine the extent to which monotony may impair individual performance, physical rate and transcultural crew performance. The facilities consisted of either one main chamber or two chambers; separated groups lived on a schedule typical for Mir station crews then on a fixed work–rest schedule mimicking International Space Station (ISS) assembly operations [8]. Specific feature of SFINCSS was the participation of several small-size and multinational crews. Lessons learned from ISEMSI, EXEMSI, HUBES and SFINCSS provided an overview of issues involved in the design and habitability of simulators and simulation campaigns.



Figure 17.4 Mars-500 experiment in Moscow/Russia (Image © Ethospace).

Over an 8-month duration, Concordia South Pole station hosted winterers in high isolation and confinement conditions approaching those found in very long-term interplanetary flights. The facility consisted of two cylindrical structures designed as a space architecture [9]. Antarctica is the farthest and most hostile environment on Earth because of the lowest outside temperatures, the windy and sunny conditions that require the crew being strictly isolated and confined for safety reasons. The inner volume of habitat is very large compared to all other space simulators. Concordia station is furnished with a life-support system analogous to that implemented onboard the European Columbus module in the ISS. Such extreme environment addresses socio-psychological and medical issues of a relatively large-size and binational (French and Italian) crew.

Over a 507-day duration, Tara expedition in Arctic was a polar schooner that once embedded in the ice, drifted on the pack until reaching the free oceanic waters [10]. Tara was not originally devoted to space researches but the drift was analogous to a flight to Mars and return to Earth. The very small volume of habitat and the very hostile surrounding in North Pole were actually relevant features of a confined and isolated environment. The crewmembers, named Taranauts, experienced continuous polar night (the sun disappeared for more than 4 months) and continuous polar day for more than 3 months, like at Concordia. The large-size crew was multinational and mixed-gender and composed of scientists, technicians, medical doctor, artist, photographer, sailor and diver. The heterogeneity of the crew was specific to Tara expedition. The dangerous nature of such mission in real conditions addressed stress and coping issues.

Over a 520-day duration, Mars-500 experiment was the longest designed analogue Mars mission of the world [11]. This experiment was conducted entirely in confinement scheduled on a 250-day interplanetary flight from Earth to Mars, a 30-day Mars orbital stay and surface operations, and a 240-day interplanetary flight from Mars to Earth. Furthermore, a 20-minute delay communication was simulated with unexpected tests of loss of communication. Mars-500 facilities were composed of four hermetically sealed chambers for ensuring life-support functions: the habitable module, the medical module, the storage module and the Mars-landing module. They were connected to an external module: Martian surface simulator. The Marsionauts were only males but involved Russian, European and Chinese cultural backgrounds. They were separated into orbital crew and landing crew, the latter one simulating EVAs while walking on the Mars surface. Mars-500 provided a

unique insight into human factor and cultural factor issues for future explorers of distant planets. The emphasis was on crew autonomy.

Over a 730-day duration, Biosphere 2 was a concept similar to the housing structure on extra-terrestrial environment. It was the longest experience in the field. The facilities were built to mainly be an artificial, materially closed ecological system and to explore human colonization of other planets. The wide landscape integrated fauna, flora, mountain area, desert area, water area and any atmospheric parameters in order for the crew to survive. The crew was specifically composed on a male/female quota. Biosphere 2 project was a full-scale life-support model and the adaptation of crews to isolated and confined environment beyond two years opened new issues for creating new ground-based simulations devoted to space science.

Other older settings about polar missions at Vostok and Mac Murdo, for instance, are permanent Antarctic stations which particularly emphasized the isolation parameter whereas submarine missions were relevant to the confinement parameter. Designing and building environments for humans in outer space is the main challenge to ensure and study isolated and confined crews' behavioral health [12]. New programs are being launched today. Several 7-day missions in the Human Exploration Research Analog (HERA) habitat at NASA Johnson Space Center in Houston, Texas, are planned to emulate what might be required on a mission to an asteroid. The current Hawaii Space Exploration Analog and Simulation (HI-SEAS) in a sealed Dome near Mauna Loa volcano is conducted for the next 8 months, to train for what conditions would be like on Mars.

In the future, the replication of such protocols would be needed for salient scientific outcomes. We could consider a continuous study, on a permanent site, within a unique facility, with a crew change every 500 days.

Acknowledgement

Special thanks to Pr. Christian Tamponnet for his support.

References

- [1] Canadian Space Agency–CAPSULS. www.asc-csa.gc.ca/eng/astronauts/osm_capsuls.asp
- [2] NASA–NEEMO. www.nasa.gov/mission_pages/NEEMO/index.html
- [3] Mars Desert Research Station–The Mars Society mdrs.marssociety.org

- [4] Collet, Jacques. “The first European simulation of a long-duration manned space mission.” In *Advances in Space Biology and Medicine*, edited by Sjoerd L. Bonting. Greenwich London: JAI Press Inc., 1993.
- [5] Vørnes, Ragnar J. “EXEMSI: descriptive of facilities, organization, crew selection, and operational aspects.” In *Advances in Space Biology and Medicine*, edited by Sjoerd L. Bonting. Greenwich London: JAI Press Inc., 1996.
- [6] Tafforin, Carole, and Alessandro Bichi. “Global Analysis of Scientific Data from the three experimental campaigns for European Manned Space Infrastructure.” In *Proceeding of the 26th International Conference on Environmental Systems*. Monterey, California, United States. SAE International # 961442, July 1993.
- [7] Flashline Mars Arctic Research Station–The Mars Society. <http://www.fmars.marssociety.org>
- [8] Mohanty, Susmita, Sue Fairburn, Babara Imhof, Stephen Ransom, and Andreas Volger. “Survey of past, present and planned human space mission simulators.” In *Proceeding of the 38th International Conference on Environmental Systems*. San Francisco, California, United States. SAE International # 2008-01-2020, June 2008.
- [9] Institut Paul Emile Victor–Concordia. http://www.institut-polaire.fr/ipev/bases_et_navires/station_concordia_dome_c
- [10] Home–Tara. <http://arctic.taraexpeditions.org>
- [11] European Space Agency–Mars500. www.esa.int/Our_Activities/Human_Spaceflight/Mars500
- [12] Harrison, Albert A. “Humanizing Outer Space: Architecture, Habitability, and Behavioral Health.” *Acta Astronautica* 66 (2010): 890–896.

