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Human Spaceflight: ESA’s Pathway to Exploration

Mars 500 simulates a mission to Mars and is therefore an important part of Europe's pathway to exploration. Paving the way for human exploration activities in space, such as future missions to the Moon and Mars, is one of the two main aims of ESA’s Directorate of Human Spaceflight. The other aim is to implement Europe's participation in the development of space infrastructure, such as the International Space Station. To this end, the Directorate also supports the development of research and technologies on Foton capsules, sounding rockets, parabolic flights, and drop towers.

In the framework of the European Programme for Life and Physical Science (ELIPS) this research and technology development makes it possible to perform experiments in the weightless environment of space, which will benefit people on Earth whether through scientific or technological advancement or the education of our youth and also prepare Europe for the new challenges of human space exploration. In support of these activities ESA’s Directorate of Human Spaceflight has an astronaut corps that was extended in May 2009 from 8 to 14 Europeans who are training for the upcoming missions to cover ESA’s future human spaceflight activities.

Development of space infrastructure such as elements of the International Space Station (above) is one of the main goals of ESA’s Directorate of Human Spaceflight. (Image: NASA)

We are entering a new era of historic significance, in which we will extend human presence beyond Earth’s orbit, both physically and culturally and to this end ESA was one of the 14 space agencies that signed up to the Global Exploration Strategy.

ESA and its partners plan to return to the Moon and beyond with the goal of sustained and ultimately self-sufficient human presence beyond Earth. This is an enormous challenge, and one that no nation can undertake on its own.

Within this cooperative framework ESA has developed its strategic goals, which fulfil an important role within global exploration activities.
Within the cooperative framework of the Global Exploration Strategy ESA and its partners plan to return to the Moon, Mars and beyond with the goal of sustained and ultimately self-sufficient human presence beyond Earth. (Image: ESA)

whilst at the same time providing ESA with the opportunity to make significant advancements in its own technologies, and increasing the depth of experience Europe has within its astronaut corps and ground teams. On the technological side with respect to space infrastructure, ESA is working towards its exploration goals within such projects as the Advanced Re-entry Vehicle and the Lunar Lander, projects which are respectively building up to Europe’s capabilities within human transportation rated vehicles and logistics supply outside of low-Earth orbit. ESA’s development of technologies on all the main areas of life support has been ongoing for more than 20 years and are/have been used in modules such as Columbus and the ATV.

Further advancements in life support systems are continuing with systems such as the Advanced Closed Loop System (ACLS), the air constituents analyser ANITA, and the Micro-Ecological Life Support System Alternative (MELiSSA) with additional developments ongoing in areas such as air and water recycling, waste management, food production, contaminant measurement and control. Other technological advancements, which are also under development include concepts such as inflatable modules for habitation, human robotic assistance, and novel power generation and management systems.

The Concordia Station in the Antarctic, which acts as a test bed for life support and environmental control system technologies. (Image: IPEV)

In addition to developing the necessary space infrastructure for exploration missions ESA’s Directorate of Human Spaceflight also has an ongoing programme of ground-based activities to make sure that our astronauts are prepared as much as possible in the future for the physical and mental demands of long-duration exploration missions, and development of countermeasures against any adverse effects of such a mission. This includes participation in isolation studies, such as Mars 500, which will determine various physical and psychological affects of a long-term period of isolation as would occur during a prospective Mars mission, and bed rest studies, which provide the opportunity to study the physical effects of a long-term period without the significant effects of gravity.
Mars 500: Study Overview

Human exploration of our Solar System is an important focus for the European Space Agency which has started on the path to making this a reality. Making sure that our astronauts are prepared mentally and physically for the demands of long-duration exploration missions is imperative to a mission’s success. On 3 June 2010, ESA will start as the prime partner of Roscosmos and the Russian Institute for Biomedical Problems (IBMP) in Moscow on a joint 520-day isolation study to simulate a future human mission to Mars. The study follows on from the successful completion of the initial 105-day isolation period of the Mars 500 study in July 2009.

ESA’s Directorate of Human Spaceflight has a long-standing tradition of conducting research on the physiological and psychological aspects of spaceflight. ESA’s bed-rest studies, in particular, are at the forefront of scientific research to understand how the human body reacts under weightless conditions, in order to devise effective countermeasures and enable humans to effectively undertake long-term missions in space. Mars 500 is part of these scientific efforts to prepare for future human exploration missions.

When preparing for long-duration space missions beyond the 6 months range currently undertaken by Expedition Crews on the International Space Station (ISS), medical and psychological aspects become an issue of major importance. When contemplating missions beyond Low Earth Orbit, such as to the Moon and Mars, daily crew life and operational capabilities may be affected by
the hazardous space environment, the need for full autonomy and resourcefulness, the isolation, the interaction with fellow crewmembers and other aspects.

A better understanding of these aspects is essential for development of all necessary elements of an exploration mission. Whereas research onboard the ISS is essential for answering questions concerning the possible impact of weightlessness, radiation, and other space-specific factors, other aspects such as the affect of long-term isolation and confinement can be more appropriately addressed by the use of ground-based simulations.

The purpose of the Mars 500 study is to gather data, knowledge and experience to help prepare one day for a real mission to Mars. Obviously there will be no effect of weightlessness, but the study will help determine key psychological and physiological effects of being in such an enclosed environment for such an extended period of time.

The participants act as subjects in scientific investigations to assess the effect that isolation has on various psychological and physiological aspects, such as stress, hormone regulation and immunity, sleep quality, mood and the effectiveness of dietary supplements. The knowledge gained during the study will be invaluable in providing the basis for the potential development of countermeasures to deal with any unwanted side effects of such a mission, and also help in astronaut selection procedures, and at a modest expense.

On the European side the Mars 500 programme is financed from the European Programme for Life and Physical Sciences in Space (ELIPS) and involves scientists from across Europe.

**Life in the Isolation Chamber**

In order to simulate a mission to Mars, six candidates (three Russian, two European and one Chinese) will be sealed in an isolation chamber in June 2010 for 520 days. This group were chosen to encompass working experience in the many fields including medicine, engineering, biology and computer engineering.

Part of the chamber simulates the spacecraft that would transport them on their journey to and from Mars and another part simulates the landing module that would transfer them to and from the Martian surface. Following the successful completion of the initial 105-day isolation period in July 2009, the full 520-day study will continue from June 2010 until the end of 2011.
Once sealed into the chamber the candidates only have personal contact with each other plus contact with a simulated control centre as would normally happen in a human spaceflight mission. For the first and last month inside the chamber the candidates will have voice contact with the control centre. For the remaining time in the isolation facility they will only have written communication with the control centre with an in-built delay of up to 20 minutes each way to simulate an actual interplanetary mission. As with a human spaceflight mission, the chosen candidates are free to take certain personal items, as well as being supplied with books and movies and can occupy themselves with physical exercise or self studies.

During the isolation period the candidates simulate all elements of the Mars mission, travelling to Mars, orbiting the planet, landing and return to Earth.

The crew have to be self reliant, organising a great deal of their daily tasks. They are responsible for monitoring and maintaining the health and psychological states of themselves and each other, monitoring and controlling and maintaining systems including life support, control resource consumption, carrying out standard and non-standard cleaning and maintenance tasks, as well as fulfilling scientific investigations.

The control centre will be manned 24 hours per day, 7 days a week with a rotational system in place to account for night shifts. Non-standard and emergency situations are also simulated to determine the effect of a decrease in work capability, sickness, and also failures of the onboard systems and equipment.

During “Mars surface operations” the crew are also divided into two groups of three people each. Once the first group exits to the Martian surface, the hatch between the Martian simulation module and the rest of the facility is closed by the second group and is only opened again when the Mars surface stay simulation has ended.
The Mars 500 isolation facility in which the study subjects are based is located in a special building on the IBMP site in Moscow. This building comprises the isolation facility itself, as well as the operations room, technical facilities and offices. The current layout of the isolation facility comprises 4 hermetically sealed interconnected habitat modules, in addition to one external module, which is used to simulate the Martian surface. The total volume of the habitat modules is 550 m³. The individual modules are as follows:

**Medical module**
The medical module is 3.2m x 11.9m and houses two medical berths, a toilet and equipment for routine medical examinations and telemedical, laboratory and diagnostic investigations. Should a crew member become ill, they can be isolated and treated here.
Habitable module
This module is the main living quarters for the crew. The 3.6m x 20m module comprises 6 individual compartments for the crew members, a kitchen-dining room, a living room, the main control room and a toilet. The individual compartments (bedrooms), which are 2.8-3.2 m², have a bed, a desk, a chair and shelves for personal belongings.
Mars landing module simulator
The Mars landing module simulator is only used during the 30 day “Mars orbiting” phase. The 6.3m x 6.17m module accommodates up to 3 crew members and has 3 bunk beds, 2 work stations, a toilet, a control and data collection system, a video control and communications system, gas analysis system, air-conditioning and ventilation system, sewage system and water supply, and a fire alarm and suppression system. The landing module simulator has two transfer tunnels, one of which leads into the simulated airlock from which to start simulated Martian surface operations.

Martian surface simulator
The module simulating the Martian surface has a volume of 1200 m³. There is an attached ‘airlock’ for storing the Russian Orlan spacesuits used by the relevant crew. The crew members entering the simulated Martian surface will wear the spacesuits at all times to simulate Martian surface operations.

Storage module
This 3.9m x 24m module is divided into 4 compartments:
- compartment 1 houses a fridge for storage of food
- compartment 2 is used for storage of non-perishable food
- compartment 3 houses the experimental greenhouse
- compartment 4 houses the bathroom, sauna and gym
The technical installations include all necessary equipment for running the study (communications and control, ventilation and air supply, water supply, electrical installations, sewage, air and water quality monitoring and partial recycling, medical equipment, fire and other safety monitoring systems, emergency equipment, etc.). The crew stay in those modules under conditions of artificial atmospheric environment at normal barometric pressure.
Candidate Selection

The candidates chosen to take part in the Mars 500 study had to fulfil many different criteria and undergo many different selection stages. The candidates are robust, emotionally stable, motivated team workers who are open to other cultures and can deal with the slightly Spartan lifestyle you would associate with an actual space mission. Not only are individuals' personality traits very important, but as a group there is the need to combine different personalities and talents together in order to create the optimal group for such an extensive exercise.

For ESA choosing the European candidates for the Mars 500 study was an extensive process with around 300 candidates applying to take part in the 520-day isolation period. From the European applicants, who met the requirements regarding nationality, age, body height, body weight, educational background and proficiency in English and/or Russian, 28 were selected to undergo a first telephone interview.

Following submission of results of medical testing, and subsequent invites, 10 highly qualified and experienced candidates gathered at the European Astronaut Centre in Cologne, Germany in January 2010 and underwent an extensive medical examination in order to determine the health status of the candidates, an in-depth psychological test also used in the pilot selection process by DLR and...
The crew members for the 520-day simulated Mars mission outside of the entrance to the Mars 500 isolation facility at IBMP in Moscow (Image IBMP/Oleg Voloshin)

a personal interview with an expert panel to determine areas such as the motivation and suitability of each candidate in question.

Of the candidates that passed this selection phase four went through additional extensive medical screening procedures in Moscow in February 2010. In Moscow they were put through their paces at the Central Clinical Hospital of the Russian Academy of Sciences. There, they underwent extensive medical examinations for several days, including an ECG at rest and during exercise, X-ray of chest and spine, ultrasound of internal organs and blood tests. There were also consultations with specialists including a neurologist, a dentist, a psychologist and an ophthalmologist. These tests were essential to ensure that the final crew was totally healthy before embarking on their mission, in fact the selection procedure followed was similar to that applicable to real astronauts.

ESA’s final four European candidates started training at the IBMP facility in Moscow in February. After completion of a four-month period of training for the mission, two of the group were chosen as prime crew to join the four other prime crew members (three Russian and one Chinese) inside the specially designed isolation facility in Moscow for the full 520-day Mars 500 study period.

X-ray diagnostics taking place during medical selection procedures prior to start of the 520-day isolation period of the Mars 500 study (Image IBMP/Oleg Voloshin)

An electroencephalogram being undertaken during medical selection procedures prior to start of the 520-day isolation period of the Mars 500 study (Image IBMP/Oleg Voloshin)
ESA Crew Members

Diego Urbina

Diego Urbina has a joint Italian/Colombian nationality and was a crew member at the Mars Desert Research Station in Utah, USA in January 2010, researching the growth of tropical plants and spacesuit constraints.

He was an Attitude and Orbit Control Systems researcher for the Aramis nanosatellite at the Politecnico di Torino in 2008. Following graduation, Urbina spent time as an outreach and educational activity organizer in the developing world. Prior to this he was an operations and astronaut training intern at the Neutral Buoyancy Facility of ESA’s European Astronaut Centre in Cologne, Germany from May to August 2009. Urbina participated in the ‘Image Reversal In Space’ (IRIS) experiment for the ISS, supporting numerous measurements for baseline data collection and testing the experiment during ESA’s 50th Parabolic Flight Campaign in 2009.

Born in May 1983, Urbina has Bachelor’s and Master’s degrees in Electronics Engineering from the Politecnico di Torino, in Turin, Italy and a Master’s degree in Space Studies from the International Space University, in Strasbourg, France. His interests include scuba diving, graphic design, drawing, fitness training and football.

Romain Charles

Romain Charles is from France and has been working for Sotira (part of the SORA group of companies) since 2005. He is currently a Quality Manager for the company, which produces composite panels and has undertaken Quality Engineer roles within the Sotira for companies such as McLaren, Aston Martin and Tesla Motors. This followed a spell as a Quality Engineer for the automotive components company Mann + Hummel after graduation in 2004. This included working on projects for the Nissan company.

Born in 1979, Charles lives in Saint Malo, France and obtained a Master’s degree in Engineering from the French Institute of Advanced Mechanics in Clermont Ferrand, France, which he attended from 1999 to 2004.

His interests include books and cinema, the internet, swimming, running and scuba diving. He is also an active member of Junior Chamber International.
Russian and Chinese Crew Members

Alexey Sitev

Alexey Sitev is a 38-years old nautical engineer who lives in Star City near Moscow. In addition to being one of the Russian crew members for the Mars 500 study he has been assigned as the commander for the Mars 500 crew. He graduated from the Dzerzhinsky Higher Military Naval Engineering College in Saint-Petersburg in 1996 where he specialised in search-rescue and deep-sea diving, and construction of methods/ships for rescue and ship-raising purposes.

From 1996 he served as the trainer-commander of a Black sea fleet platoon in Sebastopol, Ukraine. During the time of service he trained more than 250 junior specialists of the military naval fleet in deep sea diving qualifications.

In 2004 he became the leading engineer-investigator (senior diving specialist) at the Gagarin Cosmonaut Training Centre for training ISS crews for spacewalk activity in neutral buoyancy tanks, and was head of diving training.

Outside of the professional sphere Sitev is interested in tourism, photography, and diving.

Sukhrob Kamolov

Sukhrob Kamolov is one of the Russian Mars 500 candidates. He is a 37-year old surgeon who resides in Moscow. After studying at the Tajikistan Medical University until 1994, Kamolov graduated from the Russian Kirov Military Medical Academy in Saint-Petersburg in 1996, and the following year completed an internship specialising in surgery.

From 1998 he worked in the Central Military Hospital in Dushanbe, Tajikistan and worked in the department of oral surgery from 2001. From 2004 - 2006 he was a resident at the Bakulev Scientific Research Centre of cardiovascular surgery in Moscow where he participated as first assistant on heart operations. In 2009 he defended his PhD, which related to prosthesis of the aortal valve.

Rustamovich's interests include film, theatre and sports.
Alexandr Smoleevskiy

Alexandr Smoleevskiy is a 32-year old military physician/physiologist who comes from Moscow. He graduated from the Kirov Military Medical Academy in 2005 and a year later completed an internship specialising general medical practice.

From 2006 he was a researcher at the Scientific Research Test Centre of Aviation, Space Medicine and Military Ergonomics. He is a specialist on medical support of testing of aviation systems and models of military equipment, medical devices, apparatus and systems. He also worked on issues of increasing human tolerance to unfavourable environmental factors and conditions of activity. Since 2009 he has been the head of laboratory of psycho-physiological research and has investigated communication issues involving human-machine interfaces.

Smoleevskiy’s hobbies include sports and fishing in addition to his professional interests.

Wang Yue

Wang Yue is the Chinese candidate for the 520-day isolation period of the Mars 500 study. He is 27 and from Beijing. Prior to his involvement in the Mars 500 study Wang was working on environment adaptability training and selection as an assistant for Chinese astronaut training.

Wang graduated in Preventative Medicine from the Nanjing Medical College in China in 2005 and in physiology from the Astronaut Centre of China in 2008. From 2008 Wang was involved in astronaut training and selection for the Shenzou-7 mission, which included the first Chinese spacewalk, and was also involved in the preliminary selection for the second group of Chinese astronauts.

Wang’s interests include basketball, football, swimming and reading.
Pre-Isolation Training

Generic Training
Training the candidates for the full 520-day Mars 500 study got underway soon after the candidates arrived in Moscow on 24 February 2010. This started with training and lectures at the IBMP facility in Moscow, where the Mars 500 isolation study will take place. For the candidates this included practical training and lectures in preparation for their survival training, psychological training, lectures on life support systems and training in all the experiment protocols that will be undertaken during the study. This training continued over the course of the next few months.

During this period the candidates carried out their 2-day survival training in woods near to Moscow at a special base of a Moscow physical exercise institute. This was undertaken in two groups simultaneously with two Europeans in each group.

Survival Training
Following final instructions, medical checks and dressing in appropriate survival outfits for such an exercise, the groups were brought to the supposed ‘landing site’ of their spacecraft under
the premise that the spacecraft didn’t land in the expected area. Their first task was to find an appropriate place for building a shelter, lighting a fire and building a shelter for the night.

In the evening the teams received the signal that their ‘rescue helicopter’ was approaching and that
they had to prepare a landing spot, light a fire and set off signals.

Candidates around a fire set as a signal to a rescue helicopter.  
(Image: IBMP/Oleg Voloshin)

The second day they had to dismount their shelters, pack and move to an open field to be supposedly picked up by a helicopter. During this walk several medical problems were simulated (including a broken leg and unconsciousness) and medical care had to be administered. The survival training was concluded during the day.

Survival training prior to start of the 520-day isolation period.  
Top: A broken leg is simulated on the group’s journey to the rescue site.  
Middle: A makeshift splint is applied.  
Bottom: ESA Mars 500 candidate Diego Urbina (foreground) helps with moving the group’s simulated injured teammate to the rescue site.  
(Image: IBMP/Oleg Voloshin)

Top and Bottom: Candidates disassembling a tent and moving on to a rescue site as part of survival training for the 520-day Mars 500 study.  
(Image: IBMP/Oleg Voloshin)
During the survival training each group was on its own, with hourly radio contact with the support team, which included personnel and psychologists from IBMP.

**Experiment Training**

ESA, Russian and Chinese candidates had to undertake training in the ESA and Russian experiments taking place during the Mars 500 study as well as different modules and systems of the Mars 500 Isolation Facility. Training once again took place at the IBMP facility. This included lectures on the medical/technical facility, video and communication system, information system and life support system from IBMP experts and training in the facility’s gas analysis system, air purification system, and ventilation and air conditioning system.

For a majority of the ESA experiment training, Principle Investigators of the experiments were present and provided training material, lectures and hands-on training. Psychological training also took place at different times.
Scientific Protocols: Summary

Adaptation, group structure and communications of confined and isolated crews: This protocol explores some aspects linked to individual and social adaptation to isolated and confined conditions, investigating some psychological factors of the adaptation process, and some psychosocial issues related to group functioning and decision making. The aim is to better understand the psychological adaptation and its repercussions on social and organizational processes.

Association between psychological and cardiac functioning in a confined population: Inactivity is likely to play a role in cardiovascular deconditioning during long duration missions. Confinement could also produce emotional stress which could in turn lead to altered cardiovascular function and undermine the wellbeing of the crew. This study evaluates the effect of confinement and isolation on changes in the psychological wellbeing of the Mars 500 crew and will try to correlate any mood changes with changes in cardiac regulation and cardiopulmonary function.

Clinical-physiological investigations for maintaining physical fitness and body composition by resistive vibration exercise: This investigation aims at maintaining the clinical-physiological functions of the postural and locomotor system by continuous training with the Galileo 2000 system and monitoring of physical fitness before, during, and after the isolation period within the chamber.

Development and testing of an operational tool for learning, training and maintenance of space specific complex skills for object hand control with six degrees of freedom: The project proposes the development and testing of a prototype of software for educational training. The software leads participants step by step through scientifically constructed tasks to the required level of skills before confronting the subject with a complex spacecraft docking simulation to test object hand control.

Evaluation of Stress and Immunity: Previous studies have shown a change in immune response in simulated weightlessness or confinement on earth, and that mental stress is an influencing factor in this process. This project assesses the impact of long term confinement on stress-associated immune responses and will provide the basis for the development of pharmacological tools to counter unwanted immunological side effects during long-duration space missions.

Effect of blue-enhanced light on alertness and sleep-wake behaviour: Insufficient background lighting could induce detrimental physiological changes, affecting sleep, performance and metabolism. Using stimulation by blue-enriched light, an evaluation will be made of the cumulative effect of the visible light in the Mars 500 isolation chamber on sleep-wake behaviour, sleep quality, subjective alertness levels, and circadian rhythms.

Effects of group dynamics and loneliness on cognitive and emotional adaptation to extreme, confined environments: The aim of this study is to understand if long-term space flights lead to stronger feelings of stress, for instance loneliness, and whether this might have an effect on performing and controlling professional tasks.

Influence of physical activity and dietary supplements on the serotonergic system and its implications on performance and mood: This study investigates the influence of exercise with and without dietary supplements on the serotonergic system (which plays a complex
regulatory role in neurological activity) and determine its implications on mood and mental and motor performance. The supplements will be branched-chain amino acids (BCAA) or Tryptophan (TRP), which are important dietary amino acids.

**Medical skill maintenance during long duration spaceflight:** This protocol will make an assessment of retention of theoretical and manual medical skills, and an evaluation of refresher training courses at different times during the isolation study as an appropriate countermeasure against the loss of medical knowledge.

**Mission Execution Crew Assistant (MECA):** The aim of this experiment is to develop a prototype Mission Execution Crew Assistant (MECA), which would be capable of supporting human/machine interaction during long-duration spaceflight. MECA will empower the cognitive capacities of human-machine teams during planetary exploration missions in order to cope autonomously with unexpected, complex and potentially hazardous situations. The goal is to encourage human and machine groups to act in a distributed, autonomous but cooperative way.

**Neuro-Immino-Endocrine and metabolic effects of long term confinement:** The short term objective of this study is to verify the impact of isolation/confinement on immune function and hormonal parameters including those involved in appetite regulation and gonadal function, and independent of any influence of weightlessness. In the future this could lead to the development of appropriate hormonal and nutritional countermeasures to the metabolic changes experienced.

**Omega-3 polyunsaturated fatty acid and psychological wellness during long-duration space missions:** Polyunsaturated fatty acids have important biological functions in the human body, the absence of which can cause such conditions as inflammation or depression. This study is examining the level omega-3 fats in the blood of subjects in order to suggest a supplement that might enhance psychological wellbeing.

**Personal values on missions to Mars - implications for interpersonal compatibility and individual adaptation:** During any future human exploration mission to the Moon and Mars, the psychological resilience of the crew will play a critical role for the maintenance of health and performance and hence the success of the mission. The aim of this project is to determine the implications of personal values held by individual crewmembers for compatibility within the group as a whole or otherwise, and for individual coping strategies and adaptation during long lasting confinement.
Adaptation, group structure and communications of confined and isolated crews

The Mars 500 facilities provide the unique opportunity to explore some aspects linked to individual and social adaptation to isolated and confined conditions. This protocol investigates on the one hand some psychological factors of the adaptation process, and on the other hand some psychosocial issues related to group functioning and decision making. The aim is to better understand the psychological adaptation and its repercussions on social and organizational processes (communications, interpersonal relationships).

In order to better understand the subjects’ adaptive responses, this protocol investigates: their perception of the environmental constraints; their individual adaptive processes; their recovery capabilities, especially after an episode of acute stress and after the mission; the evolution of interpersonal relationships within the crew members, focusing on crew cohesion, interpersonal tensions or even conflicts; and the efficiency of their communications under different conditions. Internal as well as external communications will be analysed.

Verbal and behavioural methods are used to carry out this protocol. Verbal methods are related on the one hand to questionnaires and tests for the investigation of the subjects’ perception of the situation and of themselves, and on the other hand to the analysis of their communications amongst the crewmembers and to the outside (control centre team, family etc.)

Behavioural methods are related to the observation of interpersonal behaviours, using a wireless monitoring system, which provides an objective record of the relationships between crewmates in combination with observation by video records.

Science Team: Karine Weiss (FR) et al.
Association between psychological and cardiac functioning in a confined population

Besides weightlessness, inactivity is likely to play a role in cardiovascular deconditioning during long duration missions. Moreover, confinement of a crew in a limited space for a long period of time, as envisaged for the Mars 500 simulation, could produce emotional stress which could in turn lead to altered cardiovascular function and undermine the wellbeing of the crew.

In normal circumstances our heart rate is influenced by the sympathetic and parasympathetic nervous systems, which in basic terms influence accelerated and decelerated bodily activities respectively. They determine our heart rate and strength of contraction and adapt these to different needs during our daily activities. The control of our heart rate receives important feedback information by the baroreflex mechanism (the relationship between heart rate and blood pressure). This monitors our blood pressure and adjusts heart rate to maintain a stable blood pressure within healthy limits.

This study evaluates the effect of confinement and isolation on changes in the psychological wellbeing of the Mars 500 crew and will try to correlate any mood changes with changes in cardiac regulation and cardiopulmonary function. The psychological evaluation of mood alterations is assessed through questionnaires filled out by the crew. This will be correlated with different physiological measurements. 24-hr ECG data comes from a portable Holter device, and additional short-duration ECG and blood pressure measurements will be taken.

Spectral analysis is used to determine circadian rhythms and sleep alterations, heart rate and blood pressure variability, the baroreflex and synchronization of cardiac activity and respiration. Additional cardiac function data is obtained using tele-echocardiography and tele-auscultation, which will give some insight into heart mechanics (echo) and hemodynamics (heart sounds).

Science Team: Andre Aubert (BE) et al.
Clinical-physiological investigations for maintaining physical fitness and body composition by resistive vibration exercise

Biomedical support of astronauts will be a major element of future missions to Mars, as weightlessness causes loss of muscle and bone mass and locomotor competence if appropriate countermeasures are not effectively administered.

The aim of the proposed project is to execute countermeasures to prevent muscle and bone loss and to stimulate the cardiovascular system by continuous training. The training programme is based on the Galileo 2000-plus vibration device which is applicable in weightlessness. During the 56-day Berlin Bed Rest Study in 2003, resistive vibration exercises were introduced for the first time, and proved to be the most effective countermeasures against loss of structure and function of muscle and bone related to immobility.

The use of the Galileo 2000 system, outfitted with a vibration isolation system (a requirement during spaceflight) has already been tested during parabolic flights though the ground-based version will be used for the Mars 500 study. A redesign of the system will incorporate sensors to monitor/measure muscle force and the effect of training.

The physical fitness of the candidates will be monitored before, during, and after the isolation period within the chamber. They will follow a defined set of test procedures at regular intervals which will monitor the development of cardiovascular and pulmonary function, muscle function, force and power as well as bone mass and strength. The candidates will exercise on the Galileo device in a standing posture and making use of springs and elastic shoulder harnesses to generate higher forces than 1g in order to make the exercise more effective.

Even though the level of physical deconditioning will not be as great as in weightlessness, noticeable deconditioning is expected for muscle function, mental and physical health and well-being of the crew.

This protocol will make an assessment of hand grip strength as a common measure of general strength; measure force and undertake motion analysis (mechanography) using the Galileo device itself; undertake spirometry for measurement of pulmonary (lung) function; and take heart rate and blood pressure measurements as well as ECG measurements. Candidate feedback will also be used for assessment purposes.

Science Team: Ulf Gast (DE) et al.
Development and testing of an operational tool for learning, training and maintenance of space specific complex skills for object hand control with six degrees of freedom.

The hand control of objects in weightlessness requires the consideration of six degrees of freedom. In open space no link exists between turns of an object around its own axes and the objects track in space. This requirement is unusual under terrestrial conditions. The control of any object under these conditions requires a higher degree of complexity in perception, cognition and motor multitasking.

This project will test educational training and diagnostic software, which will lead participants step by step and individually through scientifically constructed tasks to the required level of skills before confronting them with complex simulations for object hand control, i.e. leading them through spacecraft docking simulations.

The hand controls (similar to real space craft control sticks) as well as the prototype software were already developed in cooperation with the Institute of Aerospace Medicine of the German Air Force. They are used for the diagnostic of basic skills and compared to simulated, and actual, air-to-air re-fuelling flights with large aircrafts: a similar terrestrial task to space craft docking.

The space relevant version of the tool will use the unique properties of the Mars 500 study to test whether it really works under long-term confinement and isolation. One should imagine a crew returning from Mars but the two professional pilots are sick. There are four academically educated crew mates but without experience in manually controlling a spacecraft. A tested, verified and successful training system would greatly enhance the safety and well being of the crew in this situation.

The tasks in the software have been stylized and abstracted from the space problem with the subjects not being trained in its use. The different levels of the software vary in complexity (for each subject) from very easy to over-challenging. The training tool, which is analogous to the actual docking simulation consists of a virtual ellipsoid object controlled via a cockpit display. The object has to be controlled along given and visible pathways. The paths are visible by a series of ellipsoid rings, which have to be passed through.

Feedback on performance will be provided via the software and correlated with feedback from physiological measures (e.g. evoked potentials, skin conductance responses, heart rate changes, voice pitch changes). To have a diagnostic tool for other psychological questions on-board which is highly accepted by the crew members due to the relevance of the main task (docking) has importance for the support provision but also for scientific goals.

This protocol will help to provide a better understanding of the short and long-term effects of space flight on mental performance and motor control.

Science Team: B Johannes (DE) et al.
Effect of blue-enhanced light on alertness and sleep-wake behaviour

If astronauts are exposed to insufficient background lighting during their missions, they could experience physiological changes, which could have a detrimental effect on mission success. This could include disturbances in their sleep/vigilance, mental and physical performance, and metabolism.

The Mars 500 crew members wear a small sensor around their necks that analyses the light in the module as part of this protocol to understand the influence of blue-coloured light on mood and performance. (Image: ESA)

A new visual sensory system has recently been discovered in humans: a non image forming visual system which detects light irradiance. The sensitivity of this new visual system peaks in the blue range of the visible light spectrum. Visual light exposure has a wide range of effects in humans: synchronisation of circadian rhythms and sleep; suppression of melatonin, which regulates biorhythms; increase in cortisol levels, which affects metabolism; regulation of heart rate; contraction/expansion of the pupil; and changes in mood, alertness and performance.

Subjects are stimulated over several two-week periods with blue-enriched light. An evaluation is made of the cumulative effect of the visible light in the Mars 500 isolation chamber on sleep-wake behaviour, sleep quality, subjective alertness levels, and circadian rhythms. Individual light exposure is measured with newly-developed environmental sensors that are worn by each subject.

Sleep duration and quality is measured with a sleep questionnaire. Sleep-wake activity is continuously recorded via a small, wrist worn device (an 'actimeter', the size of a small watch). Computerised tests are used to measure participants’ alertness and mental performance, and circadian rhythms are determined by measuring melatonin levels in saliva.

Stimulation by blue-enriched light is expected to have a positive effect on circadian rhythms. A significant positive correlation between the amount of blue light stimulation and waking alertness and sleep quality in crewmembers is also expected to be observed.

Science Team: Luzian Wolf (AT) et al.
Effects of group dynamics and loneliness on cognitive and emotional adaptation to extreme, confined environments

In the last decades, the interest in the effects of stress on mood and performance has increased. One measure of stress is, for instance, loneliness. Research on Earth has shown that loneliness is related to social, physical and personal factors. It is not known however whether astronauts or cosmonauts experience loneliness during a long term space flight, and what the effects may be on their mental processes.

The aim of this study is to understand if long-term space flights lead to stronger feelings of stress and whether this may affect performance. (image: ESA)

Results of this study will help to improve our understanding of the concerns and attitudes of space crew and personnel towards prevention and control of stress and stress-related problems.

It will also benefit on-going research by providing data, which could lead to the development of new procedures for crew selection, routine and emergencies operations, and countermeasures for use in future long-duration space flight and Antarctic programmes.

Science Team: Berna van Baarsen (NL) et al.
Evaluation of Stress and Immunity

From previous studies, the capability of a human being to defend themselves against infections showed clear changes in response to simulated weightlessness or confinement on earth. Interestingly, these changes appeared to be associated with mental stress experienced by the participating individuals.

This project assesses the impact of long term confinement on stress-associated immune responses. Determination of reactivity towards bacterial, viral and fungal antigens are assessed using blood samples from the crew members. One of the major defence mechanisms of the human immune system is white blood cells ("leukocytes"). These cells might become either "over-activated" or "depressed" and such a situation may render the organism more susceptible to tissue damage by "over-activated" cells and infections by "depressed" cells, respectively.

Additional verification of these effects on cellular metabolism are determined by measuring elements such as blood purines.

To test for possible unwanted effects on the neuroendocrine system and on immune response, blood, saliva, and urine samples are analysed, as well as parameters from exhaled breath, for indications of cellular stress and tissue damage.

The functional changes or alterations of immunity will be correlated to stress responses determined by stress tests, measurement of neuropeptides (which are neural regulators) and 'new' stress hormones like endogenous cannabinoids. Metabolic changes and the physical adaptation process to long term confinement will be also assessed and correlated with changes in immune response.

This project will help to provide a better estimate of the overall effects of extreme long-term confinement on immune response and provide the basis for the development of pharmacological tools to counter unwanted immunological side effects during long-duration space missions.

Science Team: Alexander Chouker (DE) et al.
Influence of physical activity and dietary supplements on the serotonergic system and its implications on performance and mood

Long duration space flights have provided a considerable amount of scientific research on human ability to function in extreme environments. Findings indicate that long duration missions take a toll on the individual, both physiologically and psychologically, as entry into a gravity-free environment, and living in it, is a novel situation for humans which the body may perceive as stress.

Medical interest in exercise as a countermeasure to mood changes has recently re-emerged. Special attention was given to alterations in the serotonergic (5-HT) system which plays a complex regulatory role in neurological activity and is known to influence the adaptation of e.g. mood, vigilance and performance.

This study investigates the influence of exercise with and without dietary supplements on the serotonergic system in healthy but confined subjects and determine its implications on mood and mental and motor performance. The supplements are branched-chain amino acids (BCAA) or Tryptophan (TRP), which are important dietary amino acids.

Responses of the serotonergic system are evaluated by analysing blood samples taken every 35 days during confinement. Effects of exercise on mood and motivation are monitored using electroencephalography (EEG), questionnaires and performance tests.

The hypothesis is that impairments in mood due to the isolation and confinement, together with a lack of physical exercise lead to decreases in mental and motor performance whereas physical exercise linked with dietary supplements will improve mood and therefore performance irrespective of the environmental restrictions.

Science Team: Stefan Schneider (DE) et al.
Medical Skill Maintenance During Long Duration Spaceflight

Medical support of crew members under extreme environmental conditions (e.g. weightlessness), which significantly alters human physiology over time and with limited or lacking access to medical expertise is a major challenge of long term space missions. This is even more poignant for a human mission to Mars lasting around 500 days where telemedical support will not be possible during major parts of the flight, and even when available, would involve a large delay up to 20 minutes.

Taking this into account crew members medical skills should reach and be maintained on a sufficient level during a long duration space flight. It is therefore important to provide the crew with an adequate medical training to deal with the special conditions and changes, the limited resources and the medical inexpertness of the majority of the crew. Training should protect the crew if possible from a severe loss of knowledge during the mission.

The simulator uses an array of programmed systems such as cardiovascular, pulmonary, pharmacological, metabolic and neurological. Any patient profile can be created or modified from pre-configured profiles to offer a specific set of parameters, such as an astronaut after one week in weightlessness. The crew will be trained in the most likely and most severe life threatening conditions, like myocardial infarction, burns and hypovolemic shock. The crew should be able to manage these emergency scenarios after the training.

An assessment will be made of retention of theoretical and manual skills and evaluation of appropriate countermeasures against the loss of medical knowledge at different times during the isolation period. The crew will be divided into two groups. Only one group will obtain refresher courses at regular intervals (every 60 days). These courses consist of narrated lectures, instruction films, paper-based manuals and digital teaching material. The respective standard of knowledge will be assessed via digital questionnaires and simulated emergency situations. The crew’s actions will be videotaped during the handling of these situations. The performance will then be evaluated concerning success or failure of certain procedures and the required time. The results of each crewmember will then be transformed into a numeric score.

Science Team: W Mann (DE) et al.
Microbial Ecology of Confined Habitats and Human Health

Where ever humans live micro-organisms will populate the habitat. Not only will a specific microbe community develop but also a particular ‘Mobile Genetic Elements’ pool through which the microbial population can exchange information. Several studies with cosmonauts have shown that during long-term stays on the International Space Station (ISS), the number of opportunistic pathogens increased while the population of certain protective micro-organisms decreased in the skin and intestinal microflora.

Prolonged human confinement in isolated habitats, often combined with particular features of waste disposal, personal hygiene, weightlessness, high oxygen content, and conditions such as localised high temperature, and humidity, and concentrations of metabolites will influence the microflora population from the crew members and the habitat. This situation can potentially result in undesired accumulation and proliferation of microbes on structural materials of the interior of the habitat (metals, polymers) and systems of life support (water tanks, air filters, etc.), which may cause a risk for crew infection and material deterioration possibly resulting in hardware and equipment malfunctioning.

In this study the microbial population present and developing in the Mars 500 habitat will be monitored. Microbial samples will be taken from all possible reservoirs of microbes such as the atmosphere, surface, water, food, waste and greenhouse reservoirs and the crew members, at several time points during the isolation period.

Microbial food supplements will be administered to some crew members to evaluate their beneficial effect in strengthening mouth and intestinal microflora and the immune system. This will contain a probiotic bacterium of the genus Enterococcus. The supplements may also supply beneficial elements (e.g. antioxidants) to the crew that will help deal with environmental and nutritional stress during long-term space missions.

In addition, new antimicrobial chemical products will be tested to prevent microbial contamination on surfaces of the habitat. Such products may reduce biosafety risks by improving the sanitary and hygienic quality of life for the crew as well as prolonging working life of inner structural materials inside the closed habitats.

Investigating the physiological potential of the spore-forming and/or heat-tolerant isolates from closed habitats with respect to resistance against low pressure, desiccation, UV-and ionizing radiation, and oxidative stress will give insights into the potential of these microorganisms to survive spacecraft cleaning/sterilization and/or ambient Martian conditions.

The scientific information to be obtained by this protocol is essential for the design of scenarios to prevent, monitor and counteract microbial hazards for the crew during future long duration space missions, such as to Mars and to collect bioburden and biodiversity data for the development and implementation of planetary protection guidelines for manned Mars missions.

Science Team: P Rettberg (DE) and F Canganella (IT) et al.
Mission Execution Crew Assistant (MECA)

The aim of this experiment is to develop a prototype Mission Execution Crew Assistant (MECA), which would be capable of supporting human/machine interaction during long-duration spaceflight. MECA will empower the cognitive capacities of human-machine teams during planetary exploration missions in order to cope autonomously with unexpected, complex and potentially hazardous situations. The goal is to encourage human and machine groups to act in a distributed, autonomous but cooperative way.

The isolation period will be used to collect data on performance, cognitive task load, emotion and crew collaboration and make use of game theory and data mining algorithms for analysis.

The crew will be divided into two teams of three crew members for the complete mission. Once a week, for half an hour, each team will perform three consecutive tasks: Coloured Trails, Collaborative Trainer, and Lunar Lander. The participants will each use a laptop and will only use a chat function to communicate with other members in the group.

Before, during and after the tasks the crew will be prompted with questionnaires to assess crew status (emotion and cognitive task load) and collaboration (trust and rationality). The chats are logged for analyses.

Coloured Trails is a three-player negotiation game consisting of a 4x4 five-coloured square with each player starting on one of the coloured squares and having a few coloured chips in their possession. The aim is to reach a ‘goal’ square marked with a flag by moving across the different coloured squares either vertically or horizontally. To move across a certain coloured square a player needs a chip of that colour. The crew members therefore need to negotiate and renegotiate for exchanging chips. Two of the players are ‘proposers’ while the third player is a ‘responder’. Once the negotiation process is complete, the experiment server calculates the best possible position each player can reach with respect to the goal square and taking into account the resources (chips) they would need to use and what they would have left over.

The Collaborative Trainer is based on an interactive documentation system aimed at training or re-training in the correct use of technical equipment (e.g. medical devices). Each group consists of two ‘students’ and one ‘teacher’, with roles changing each week. The students find specific instructions and questions to each assignment in a manual while the teacher observes the students, gives hints and monitors progress.

The third part, Lunar Lander, is an computer game whereby the crew members have to pilot a lunar landing module for safe touch down on the surface of the moon using control over main and rotational thrusters.

The long term goal of this experiment will be to develop an “electronic partner” helping the crew on interplanetary missions to assess situations (such as capabilities and resources), perform nominal operations adequately, determine a suitable course of actions to solve a problem and safeguard the astronauts themselves from failures.

To develop and refine credible tools and models for such an interplanetary mission it is necessary to obtain relevant empirical data from such environments/studies as Mars 500.

Science Team: Mark Neerincx (NL) et al.
Neuro-Immino-Endocrine and metabolic effects of long term confinement

Space missions have shown to induce a series of slowly reversible physiological adaptations resembling aging. It is not yet clear which is the contribution of exposure to weightlessness and of which is due to environmental stress. It is crucial to know the extent to which long-term isolation/confineent can cause adverse adaptations in the immune system, hormone regulation and metabolism especially since chronic stress can cause physiological changes leading such conditions as insulin resistance, inflammation, and clogged arteries (atherosclerosis).

The stress due to isolation and confinement is expected to cause an increase in cortisol and a disturbance of circadian rhythms, eventually impacting upon appetite-regulating hormones, the immune system and the so-called hypothalamic-pituitary-gonadal axis, which plays critical part in reproductive and immune system regulation. Should this be the case, a series of countermeasures have to be thought of in time before sending astronauts to Mars.

The short term objective this study is to verify the impact of isolation/confineent on immune function and hormonal parameters including those involved in appetite regulation and gonadal function, and independent of any influence of weightlessness. In order to study these potential effects blood plasma, 24-hr urine and saliva samples are collected at variable intervals and analyzed for various parameters. This includes neurotrophins (necessary for nerve cell survival), adrenal and gonadal steroids, cytokines (used in cellular communication such as in immune system regulation), ghrelin (a hormone important in appetite regulation) and immune cells.

The long term objective is the development of appropriate hormonal and nutritional countermeasures to the metabolic changes experienced. Such countermeasures will not only be of great benefit for astronauts/cosmonauts during long-duration missions but will also hold very important benefits on Earth in the field of geriatrics to prevent or at least decrease the high cardiovascular risk associated with metabolic syndrome, a cluster of deadly symptoms and conditions strongly related to chronic stress.

Science Team: Felice Strollo (IT) et al.
Polyunsaturated fatty acids are fats normally found in our body and cells with important biological functions, the absence of which can cause such conditions as inflammation or depression. A good balance between these fats (namely omega-3 and omega-6) is suggested as part of a healthy diet, or during illness. Fish consumption more than 3 times a week is suggested or in some cases the use of supplements. It as been reported that omega-3 may play a role in nervous system activity improving cognitive development and learning.

Low dietary intake of omega-3 polyunsaturated fatty acids has been linked to several characteristics of psychiatric symptomology, including depression, disorders of impulse control, and hostility. Preliminary intervention trials with omega-3 fatty acid supplementation for clinical depression and other disorders have reported benefits. The effects on depression have led to the conclusion that Omega-3 might affect not only cognitive functions, but also mood and emotional states and may act as a mood stabilizer.

The aim of this study is to examine the level of omega-3 fats in the blood of subjects during long term confinement, in order to suggest a supplement that might enhance psychological wellbeing, and counteract depression and mood instability, which could occur in these situations and thus affect an astronaut's performance.

Blood samples are analyzed for fatty acid profiles during the study. This data will be correlated with psychological measures and stress hormones levels, also taken during the study.

Science Team: Bruno Berra (IT) et al.
Personal values on missions to Mars - implications for interpersonal compatibility and individual adaptation

During any future human exploration mission to the Moon and Mars, the psychological resilience of the crew will play a critical role for the maintenance of health and performance and hence the success of the mission. One factor impacting on psychological resilience is the personal values of crew members defining their motivational goals and attitudes.

The aim of this project is to determine the implications of personal values held by individual crewmembers for compatibility within the group as a whole or otherwise, and for individual coping strategies and adaptation during long lasting confinement.

This project also assesses how value hierarchies of crewmembers change over time. Personal values will be studied in the framework of the Schwartz theoretical model that distinguishes between ten types of values, each of which expresses a distinct motivational goal: power, achievement, hedonism, stimulation, self-direction, universalism, benevolence, tradition, conformity and security.

During the mission, differences in values between crewmembers are related to measures of interpersonal compatibility and tension, and difficulties associated with co-working and co-living. Also, transformations of individual value hierarchies are monitored and related to individual coping strategies and adaptation.

Measures of adaptation include mood, sleep, and blood plasma levels of cortisol. Results from the project may assist in improving crew selection procedures and training for Mars missions, and add to our understanding of human aspects of future exploration missions.

Science Team: Gro Sandal (NO) et al.
ESA and Isolation Studies

The European Space Agency has previously organised isolation studies. This has included the ISEMSI campaign in 1990 in Bergen, Norway which consisted of six male subjects and lasted 30 days, and the EXEMSI campaign in 1992 in Cologne, Germany, which consisted of 3 men and 1 woman and lasted 60 days. These campaigns were performed in shore-based deep diving complexes (hyperbaric chambers). During these two experiments, the psychology of group dynamics and individual performance under isolation and confinement were studied amongst many other topics.

In addition, much of the expertise in the area of isolation studies has been built up by the Russian Academy of Sciences Institute for Biomedical Problems (IBMP) in Moscow including the Mars 500 programme in which ESA is a prime partner. The precursor 105-day isolation period of the Mars 500 study was already concluded in July 2009.

IBMP had already organised a 1 year isolation study in 1967/68. In some of the more recent studies ESA also participated. In 1994 ESA cooperated with IBMP on the Human Behaviour in Extended Spaceflight (HUBES) study. This study, which took place at the IBMP facility in Moscow, involved a crew of 3 men and lasted 135 days. For this campaign the mission duration and the crew number, as well as many other organisational and operational aspects were modelled with respect to the EuroMir-95 mission, which at that time was due to take place the following year.

In 1999 ESA also cooperated with IBMP on the ‘Simulation of the Flight of the International Crew on Space Station’ (SFINCSS). This experiment was aimed at modelling the living conditions on the International Space Station. The simulation, which also took place at the IBMP facility, involved three crews living simultaneously in connected chambers. One crew was confined for 240 days, while a second crew stayed in the connected chamber for 110 days and was followed by a third crew, who also stayed 110 days in the same chamber. Space Shuttle and Soyuz ferry flights were simulated by several visiting crews for 8
days at a time. ESA’s main experiment during SFINCSS-99 was the Flywheel Exercise Device, which, produced positive results during the study and is currently on the ISS for future use as an exercise device for the ISS crews.

Following assessment during the SFINCSS campaign in 1999: former ESA astronaut Philippe Perrin assesses the Flywheel Exercise Device (FWED), during a Parabolic Flight Campaign in 2003 (top) (Image: ESA); and ESA astronaut and ISS Expedition 21 Commander Frank De Winne carries out activation and checkout procedures on the FWED in the Columbus laboratory on the ISS in October 2009 (Image: NASA).

In 2004 IBMP started considering using its facilities for a simulation of a full Martian mission profile (i.e. 520-700 days of isolation) and invited ESA to participate in the programme. This programme, which was given the name Mars 500, has taken shape over the past years.

Based on experience gained from isolation studies, from other terrestrial-based simulation facilities such as with bed rest studies, and of course from studies on human missions in low Earth orbit, especially within the last two decades, the European scientific and technology community has gained substantial experience in assessing the risks for humans in the space environment.

In addition to isolation studies invaluable information is also produced in such areas as bed-rest studies, which help determine effects of confinement and simulated weightlessness. (Image: Emmanuel Grimault/CNES)

In addition to being helpful in determining psychological aspects of space flight, this research combined with knowledge obtained from human spaceflight missions has been invaluable in determining human adaptation to conditions in space, as well as in the development of life support systems. This knowledge is a solid base when approaching the next frontier, namely human missions beyond Earth’s orbit, i.e. to the Moon or to Mars. This not only means additional challenges in the areas of radiation protection and human physiology, it also gives a greater importance in other areas of research and technology such as the psychological issues of long-duration spaceflight as being studied within Mars 500.
Credits

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