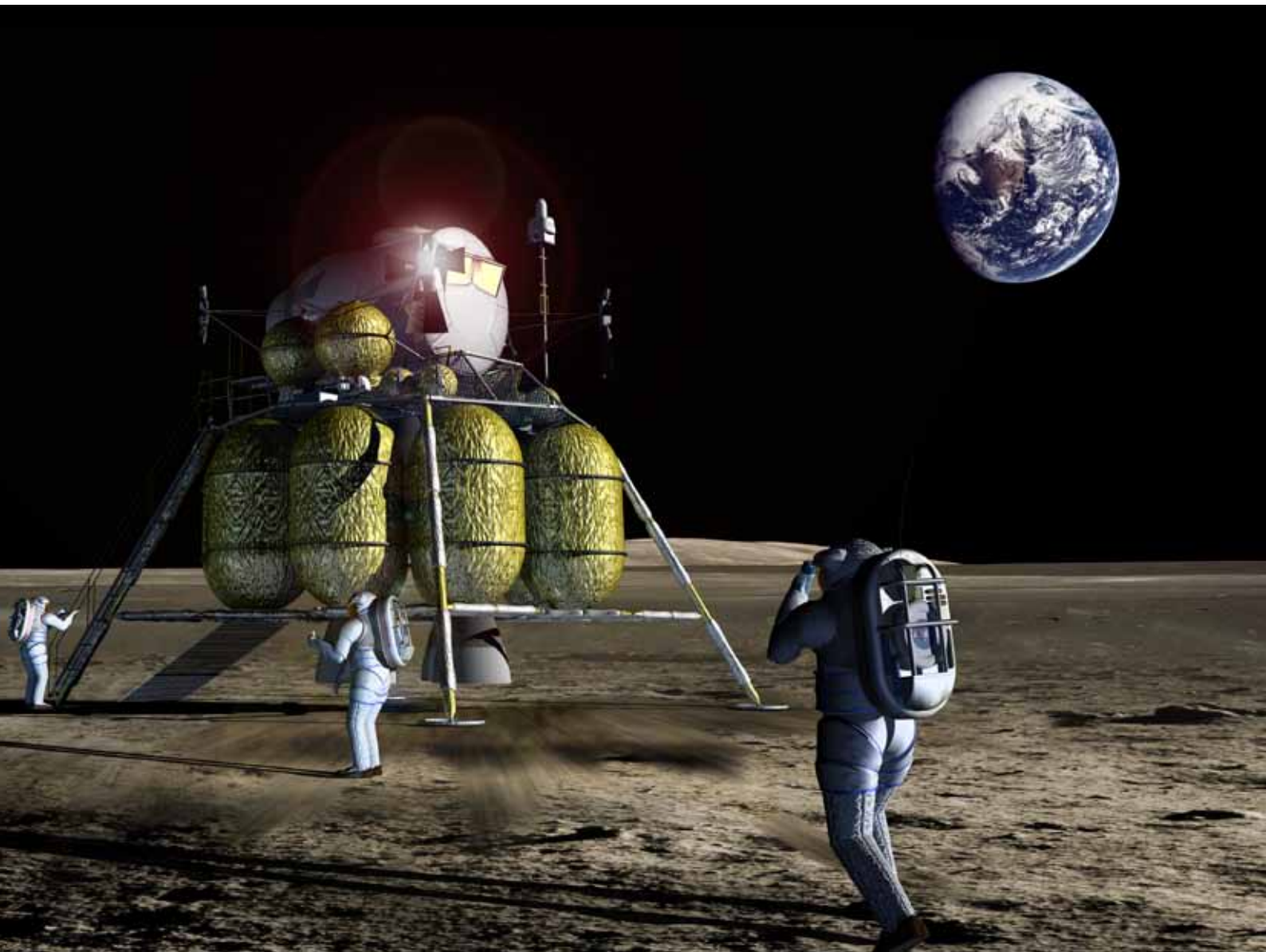


SCK • CEN

Space research



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Editing

SCK•CEN, Belgian Nuclear Research Centre

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Image front:
Simulation of a space mission. (source: ESA)

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Introduction

Mankind has always been fascinated by space. Thanks to observations and space missions, there is growing knowledge of the extreme conditions outside the atmosphere. In this way, we get more and more insight into phenomena such as increased cosmic radiation and weightlessness. Both can influence the health of astronauts and their living environment.

The Belgian Nuclear Research Centre, SCK•CEN plays an important role in space research in the fields of radiation dosimetry, human biology and microbiology.



International Space Station ISS. (source: ESA)

1

To which ionizing radiation are we exposed?

Radioactivity is a natural phenomenon. In nature, radioactive substances occur because billions of years ago unstable isotopes were formed when the Earth came into being. Some radioisotopes have a very short life and have long ago decayed. Others have a much longer life and some of them are still present on Earth today, even in our bodies.

Besides radiation from the natural radioisotopes there is also cosmic radiation, mainly from the Sun. The radiation inside a spacecraft is approximately 100 times greater than on Earth because in space there is no protection from the Earth's magnetic field and atmosphere.

How to measure the radiation?

Because the human senses cannot perceive ionizing radiation, dosimeters have been developed to detect the radiation. The Belgian Nuclear Research Centre has over 25 years of experience in dosimetry. For example, we take measurements and perform research for the industrial and medical sectors and the space travel dosimetry.



SCK•CEN uses various radioactive sources to calibrate dosimeters.

How much radiation is there inside a spacecraft?

SCK•CEN regularly sends dosimeters to the International Space Station ISS which orbits the Earth at an altitude of 400 km on average. They remain there for a few days, a few months to more than one year inside the ISS or attached to the outside. They are then analysed on Earth. These studies are conducted in cooperation with other international laboratories. The measurement of the radiation field outside a spacecraft is unique. Experts test various sensors and techniques to further improve the detection of cosmic radiation.



A box containing dosimeters of SCK•CEN is attached to the outside of the European COLUMBUS laboratory on the ISS. (source: ESA)



The solar wind carries energy-charged particles that are captured by the Earth's magnetic field and are held in the Van Allen belts (the green loops on the figure). (source: www.astronomyqcse.co.uk)

The doses of ionising radiation in the ISS vary depending on the position in its orbit. Near the equator, the dose is low; at the poles, it is higher. In addition, the Van Allen belts affect the dose in the ISS. These are two belts around the Earth containing energy-charged particles. The solar wind largely supplies them and the Earth's magnetic field retains them. At the poles, the magnetic field lines dive towards the Earth's surface and there the particles from the Van Allen belts are also closer to the Earth. Collisions with oxygen and nitrogen atoms in the atmosphere give rise to the spectacular northern or southern lights. The ISS crosses the belts three times a day and then the radiation dose can increase by a factor of 100. Since the dose in the spacecraft is already 100 times higher than on Earth, it is 10,000 times higher in the Van Allen belts.

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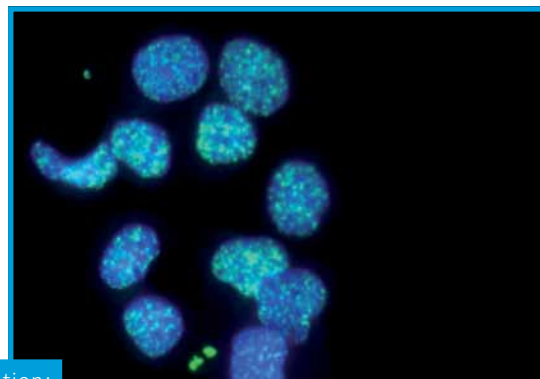
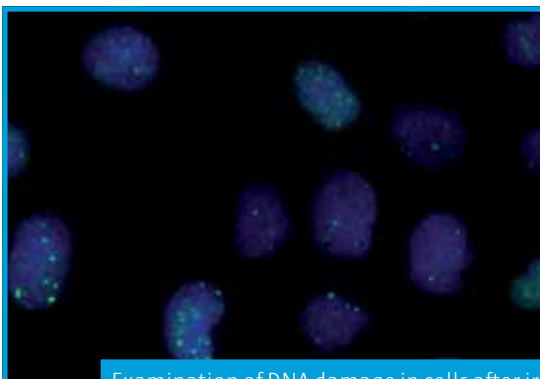
Is space travel healthy?

Scientists know that a stay in space affects the human body. Besides exposure to increased radiation and reduced gravity, problems can be caused by stress factors such as living in a confined space, work load and disturbed sleep and eating patterns.

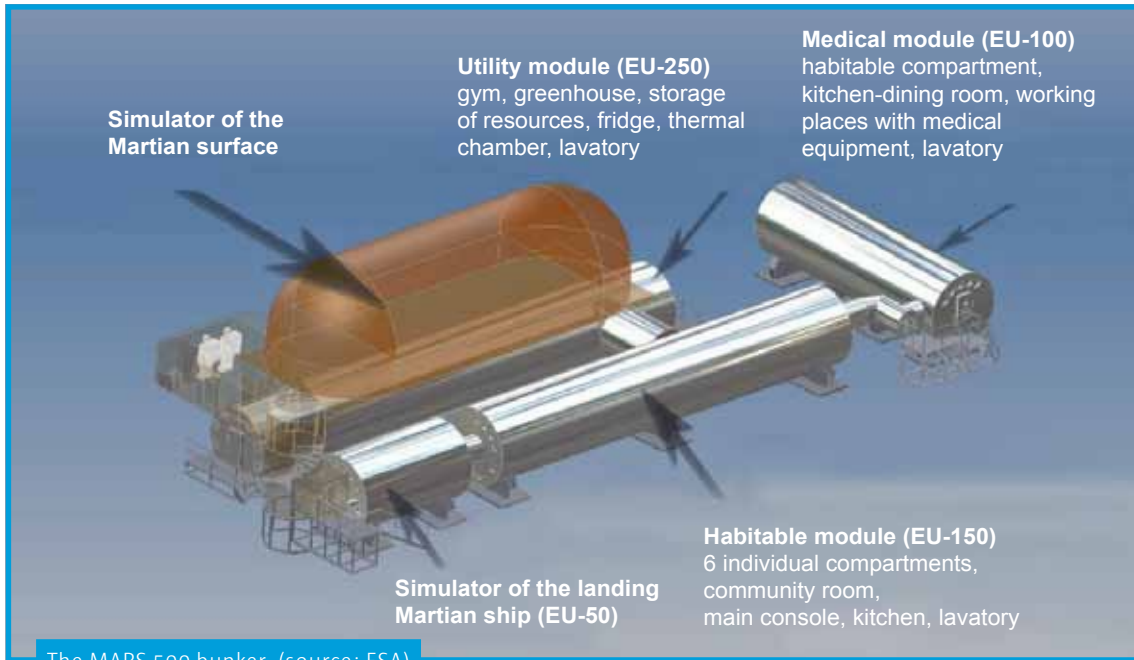
Analyses of blood from astronauts

Space travel harms the immune system of astronauts. Why this is the case and what mechanisms play a role, require further research. In cooperation with the European, American and Russian space agencies, SCK•CEN is measuring the impact of a long stay in space through the blood of astronauts. For this purpose a group of astronauts that spent six months in the International Space Station undergoes investigations using sophisticated biochemical and molecular techniques. Researchers determine the concentration of hormones in the blood serum, the cellular changes in white blood cells and examine the damage to DNA.

Each person's sensitivity to radiation is different. The sensitivity of astronauts to cosmic radiation also varies widely. This is important for long haul flights, such as to Mars, where prolonged exposure is unavoidable. Chronic exposure may affect health (e.g. cataracte) and increase the risk of cancer.



Examination of DNA damage in cells after irradiation: control cells on the left, irradiated cells on the right.



Space conditions simulated on Earth

The weakening of the immune system that is observed in astronauts during a space journey is also studied in space analogs on Earth. This is possible by means of bed rest studies, the MARS 500 bunker and the Antarctic Concordia Station.

In France and Germany, research is being performed by means of bed rest studies to investigate the changes caused by weightlessness. SCK•CEN is contributing to this research as well. During prolonged bed rest of up to 60 days the research subjects lie with their heads six degrees lower than their feet. This position induces the slow atrophy of muscles, decalcification of bones and accumulation of lymph fluid in the upper part of the body, in a similar way to what is observed in space. Within the bed rest studies, scientists are also developing methods to counteract the health effects of weightlessness. In this context, specific physical exercises, therapy, adjusted medication or food consumption are tested and compared.

The MARS 500 project is simulating a mission to Mars in which Russian and European volunteers are isolated for 520 days in a bunker in Moscow. In this project, the psychological and physiological effects of prolonged isolation of six people are being studied before, during and after their stay in the bunker.

In the Antarctic Concordia Station, people may stay isolated from the outside world for a long period of time. The station is located at high altitudes where there is less oxygen: 12-13 % instead of 20 % at sea level. This is called hypoxia. In Antarctica, the Earth's magnetic field is weaker thereby reducing the protection from cosmic radiation. These conditions (long-term isolation, hypoxia and elevated radiation exposure) also exist in the ISS and may lead to new insights into the immune system of astronauts. SCK•CEN is analysing the levels of hormones in the blood since they reflect the health and stress status of a person.

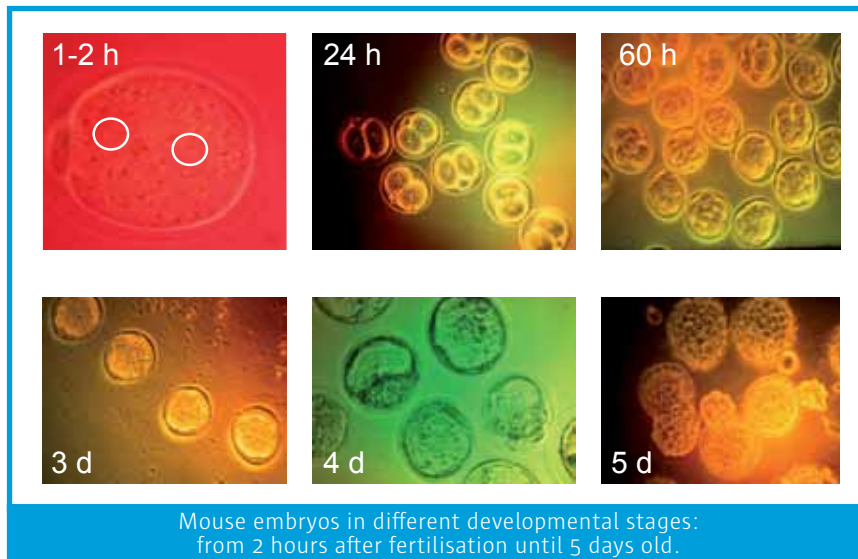
Human skin and blood vessel cells in space

The skin is the largest organ of our body. Its protective layer is very sensitive to adverse environmental factors. Damage to the skin is one of the most reported symptoms experienced by astronauts. Through space flight experiments with human skin cells, SCK•CEN is studying the biological effects of cosmic radiation and a greatly reduced gravitational force. To this end, an unmanned spacecraft containing modules of skin cells flew for twelve days in a low Earth orbit.

Besides skin cells, the cells that form the walls of the arteries are sensitive to space conditions. They rapidly become damaged in space so that the risk of haemorrhage increases. SCK•CEN is taking part in experiments in the ISS with human cells to further study the biological effects of weightlessness.



The spacecraft containing experiments is prepared for launch. (source ESA)



In its laboratories, the Belgian Nuclear Research Centre simulates space conditions using various devices. In order to simulate weightlessness, human cells are placed on a device that rotates in three directions randomly so that the cells are constantly free falling. To compare, human cells are grown in normal gravity conditions to investigate the differences in growth, morphology and genetic composition.

Impact on fertility and growth of a foetus

Can astronaut females become pregnant in space and will the baby develop normally? To answer these questions, ESA is supporting a team that studies the developmental biology of vertebrate organisms under space conditions. In this context, 33 European specialised laboratories are conducting research in the fields of physiology, molecular biology, biochemistry, behaviour, etc. at various developmental stages of the embryo.

SCK•CEN is contributing with its extensive knowledge and experience in the field of radiobiology, embryology and molecular biology. The mouse is a widely used model for molecular, biochemical and pathological studies and helps to better understand human embryology.



SCK•CEN device that rotates in three dimensions to simulate weightlessness.

3

Bacteria in space: friend or foe?

On Earth, bacteria and micro-organisms are omnipresent in millions on our skin and in our intestinal tract. We need them, but they can also make us sick. To maintain this delicate balance is very important for manned space flights. Under the influence of weightlessness and the increased cosmic radiation, both the immune system of the space travellers and bacteria behave differently than on Earth. Therefore, the Belgian Nuclear Research Centre investigates the presence and activity of bacteria in space, together with international partners.

What bacteria can we find in space capsules?

One of the projects is the characterisation of all bacteria that can live and survive in space capsules. For this purpose, SCK•CEN is using the International Space Station. At least three astronauts are continuously living in this confined space in which bacteria can accumulate. To prevent this, the American, European and Russian space agencies sterilise the materials as much as possible. In manned flights, however, the people themselves are the largest source of micro-organisms. These may eventually pose a potential hazard to the health of the astronauts and to the spacecraft.

We are working with Russian researchers from IBMP (Institute for Biomedical Problems) in Moscow to count and track the number of bacteria and fungi in the air in the ISS. The upper limit is 1000 bacterial cells per cm³ of air.



Classification of bacteria from space capsules.

Can bacteria be harmful in space?

To ascertain whether they can cause illness in space conditions, the SCK•CEN microbiologists identify the bacteria and determine their genetic content: they investigate whether they contain parts of DNA (mobile genetic elements) from other bacteria giving them the capacity to attack materials or to become resistant to disinfectants or antibiotics. This is a well known phenomenon on Earth, where for example also in the hospital setting, some bacteria become increasingly resistant to various antibiotics because new parts of DNA are taken up and integrated into their chromosome.

Together with American microbiologists, SCK•CEN examines the cooling water and drinking water from the ISS to determine the species of bacteria present and their properties. Bacteria were found that showed resistance to silver. This is not surprising because the water in the ISS is disinfected with silver ions, using the Russian system, and not with chlorine as is commonly used on Earth. In future, it is possible that the use of other appropriate disinfectants may be appropriate.



The Concordia station in the interior of Antarctica and its crew are involved in space research. (source: ESA)

Samples from space are scarce

Because samples from space are scarce, this study includes also bacterial samples from closed living and work spaces on Earth. In the Concordia station in Antarctica people are staying isolated from the outside world for long periods. Microbiologists count the number of bacteria per cubic meter of air and study how different populations have become more or less dominant. They investigate how the bacteria spread through the air, on surfaces and from one person to another during the isolation in such a closed environment, similar to the ISS.

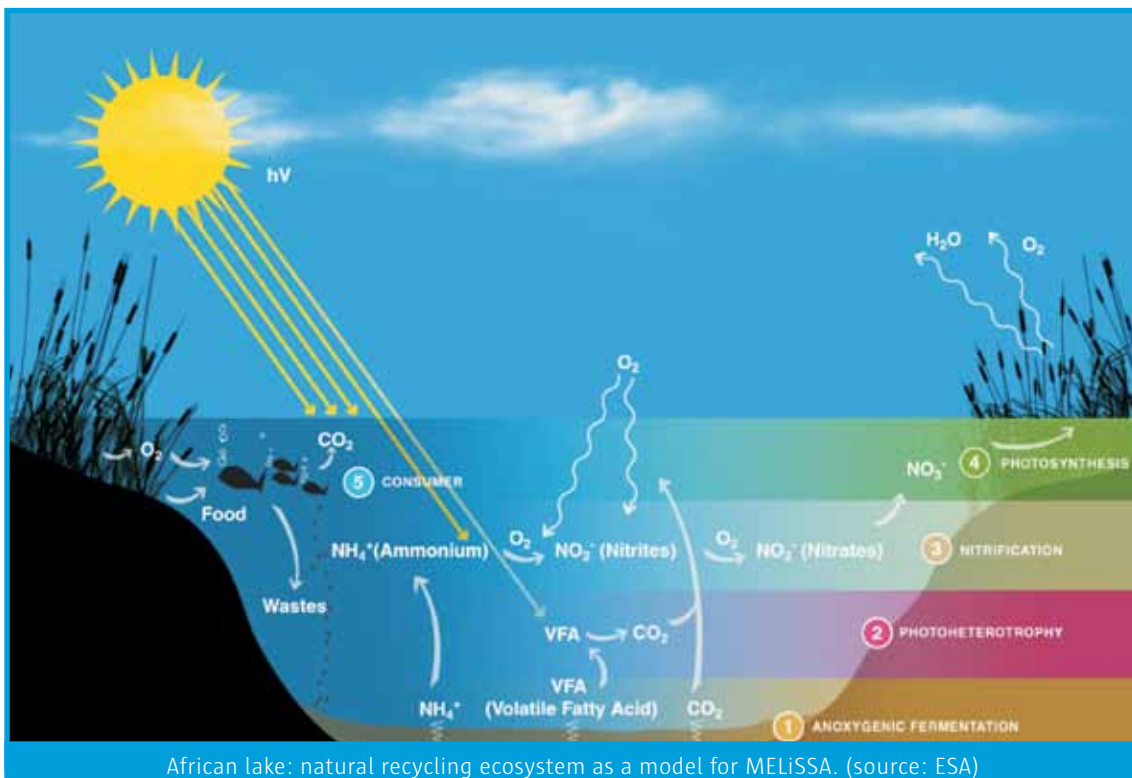
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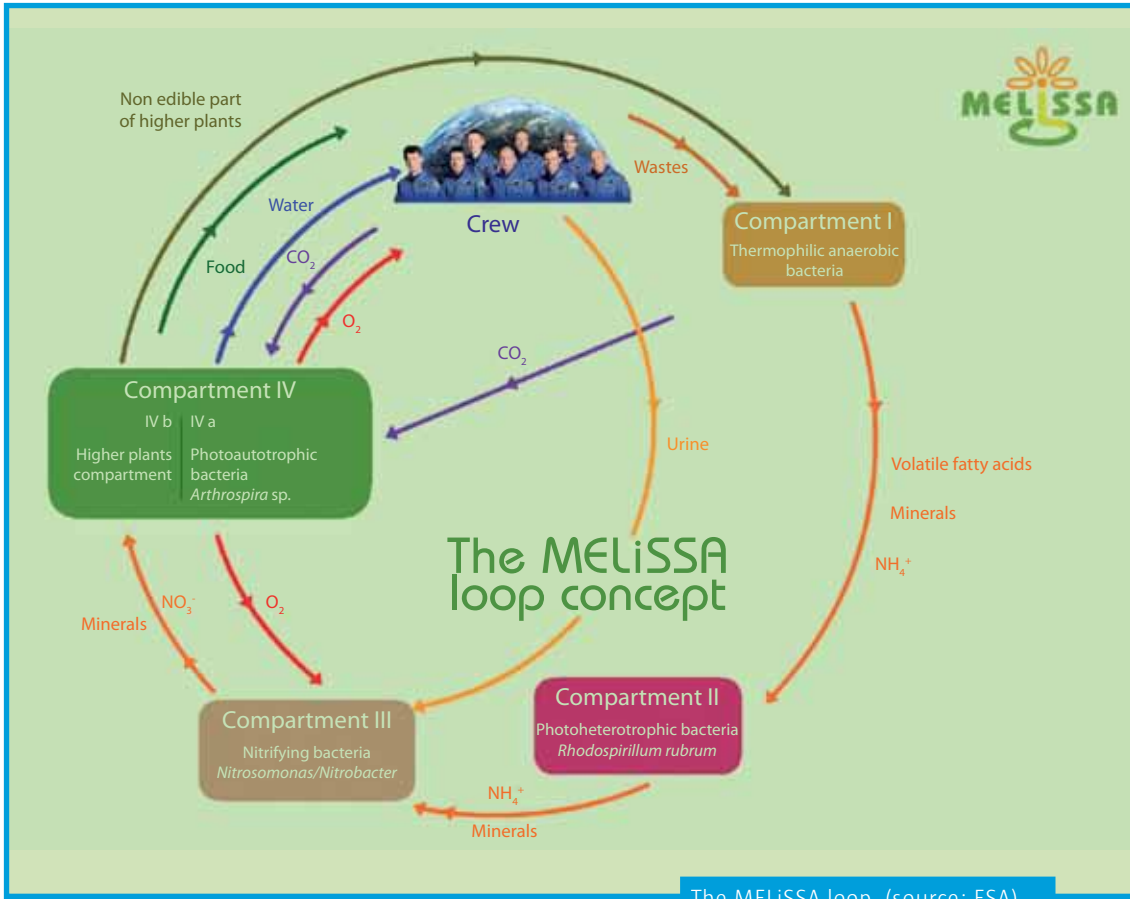
What will we eat, drink and breathe during long space missions?

An astronaut consumes daily approximately 1 kg of food, 1 kg of oxygen, 3 kg of drinking water and 15 kg of water for personal hygiene. The waste produced also consists primarily of water. For long flights, such as to Mars, the voyage and the stay combined could possibly take up 2.5 to 3 years. In such a case, it is impossible to carry sufficient water and food along and store all the waste. For that reason SCK•CEN is working with the European Space Agency (ESA) and other European partners on biological solutions for the recycling of water and the production of oxygen and food from waste.

An organic waste recycling system

About 20 years ago, ESA started to develop a high-tech bio-waste recycling system for space missions. The project was named MELISSA: Micro-Ecological Life Support System Alternative. After many years of research, an initial pilot set-up of the entire MELISSA system was built in 2009 in Barcelona (Spain). The prototype is undergoing precision testing that will support further development.





MELiSSA is a group of interconnected biological reactors (4 compartments) to recycle the waste (waste water, carbon dioxide and organic matter) into potable water, food and oxygen. Various bacteria break down organic matter to carbondioxide, ammonia, nitrates and other minerals which, in their turn, are nutrients for plants and cyanobacteria. These plants and cyanobacteria can produce oxygen through photosynthesis and are also a source of food. The cyanobacterium *Arthrospira sp.*, for example, is a quality nutritional supplement containing many vitamins and minerals.



Culture and detailed examination of the edible green cyanobacterium *Arthrospira sp.*, also known as 'spirulina' because of its spiral structure.



The red-pigmented MELISSA bacterium *Rhodospirillum rubrum* can break down organic matter without oxygen using light energy instead.

For the MELISSA-project, SCK•CEN is examining and characterising in detail each bacterium of each compartment. We are investigating whether they can still effectively accomplish their breakdown function in space where they are exposed to cosmic radiation and weightlessness. Therefore we culture the bacteria under various conditions and analyse their cell structure and cell content (DNA, RNA and proteins).

Waste recycling bacteria into space

In order to study the effects of space, the Belgian Nuclear Research Centre has sent small packets of bacteria for about 10 days to the International Space Station. Astronauts photographed the bacteria that grew in a sealed transparent box. After their return from space, they were meticulously investigated by microbiologists of SCK•CEN. A new challenge is to test also the growth and oxygen production of spirulina in a small bioreactor during a space flight.

In our laboratories at SCK•CEN we also simulate space conditions. To investigate the effects of cosmic radiation, we expose the bacteria to different radiation sources. In addition, we grow bacterial cells under constant rotation to mimic weightlessness and to study its influence.

Bacteria as soil improvers in space?

Martian or lunar soil is sterile and unsuited for agriculture. ESA grouped a team of geologists and biologists to investigate if and how bacteria and other micro-organisms could improve soil conditions. The experts examine in what way micro-organisms can release minerals, produce organic material and retain toxic compounds.

SCK•CEN contributes with its thorough knowledge of molecular biology, bacterial activity in polluted soils and high-radiation environments, and of bacterial interaction with volcanic rock, clay and toxic compounds (like metals).

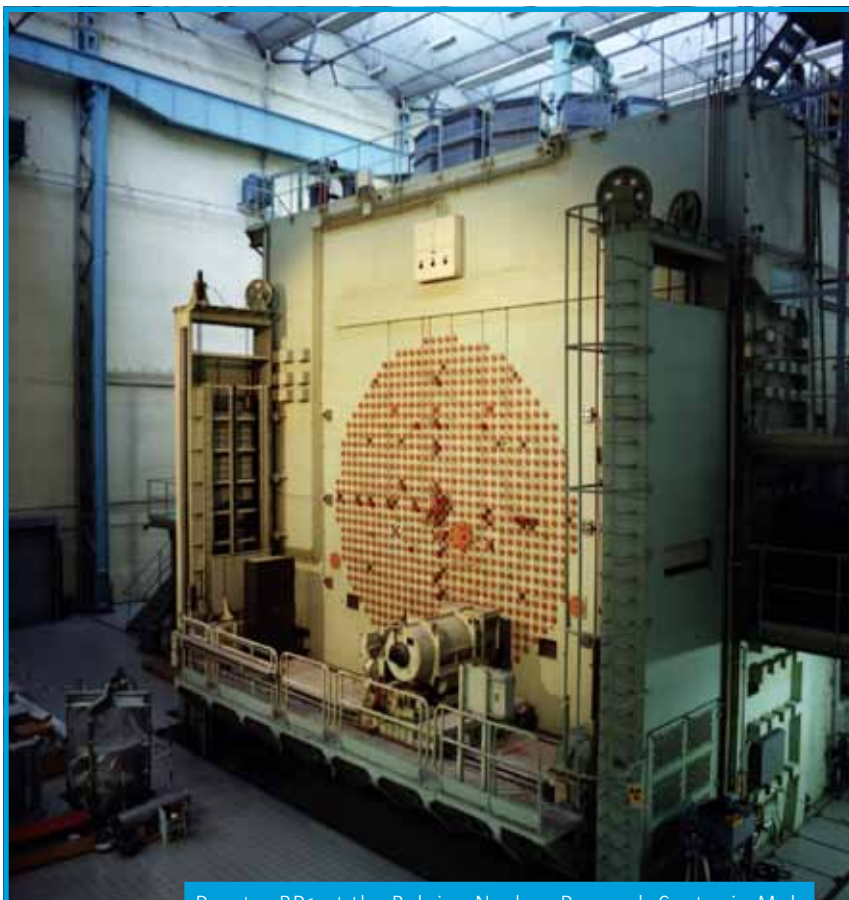


The MELiSSA bacterium *R. rubrum* grew well on its substrate during the space voyage in the ISS.

5

Reactor BR1 and cosmic radiation

To simulate and examine the influence of cosmic radiation on materials and instruments, SCK•CEN uses its reactor BR1. Commissioned by specialised agencies and companies we irradiate electronic components for space travel with fast neutrons. In this way, it is possible to determine the potential damage that high energy particles in the cosmos can cause.



Reactor BR1 at the Belgian Nuclear Research Centre in Mol.

6

Astronauts are essential for space research

The Belgian Nuclear Research Centre thanks the Belgian astronaut Frank De Winne for his active contribution to the space research of SCK•CEN and care for the experiments in space. SCK•CEN also thanks Belpo and ESA for their support.



Belgian astronaut Frank De Winne. (source: ESA)

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SCK•CEN – Belgian Nuclear Research Centre

SCK•CEN is a foundation of public utility, with a legal status according to private law, that operates under the tutorship of the Belgian Federal Minister of Energy.

Flemish Space Industries, VRI

SCK•CEN is a member of VRI (Flemish Space Industries). VRI brings together companies, research centres and educational institutions active in the aerospace sector. The association aims to put this high-tech sector on the map in Flanders and bring it to the attention of professionals and the general public.

Laboratories

SCK•CEN, Boeretang 200, BE-2400 MOL

Registered office

SCK•CEN, Herrmann-Debrouxlaan/Avenue Herrmann-Debroux 40, BE-1160 BRUSSELS

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Eric van Walle
Director-General

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SCK•CEN

Contact

SCK•CEN

Boeretang 200
BE-2400 MOL

info@sckcen.be
www.sckcen.be



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