Architecture — *[gr. architekton — one who builds according to a principle]* — art of designing and giving shape to a construction; a discipline of science and knowledge, which organizes all spaces and a set of structures. In order to solve its problems a. should make use of achievements of other technical and humane disciplines.

Architectural work — object of construction art, which is able to influence the viewer and induce some positive emotions, it has a solid structure and defined utilitarian functions.

Astronautics, Cosmotautics — *[gr.]*, a group of scientific disciplines focused on flights (*gr. nautike* — navigation) beyond the Earth's atmosphere and exploration of space and the objects it contains. Astronautics include researching and analysing conditions and phenomena related to space ship flights, creation of technical potential and its realization, as well as studying the influence of flight conditions on psychic and physical status of astronauts and their possible adaptations to such conditions.

1. Introduction.

Interest in the issue of extra-terrestrial bases has been recently growing. There are already existing stations in orbit and humans will go to Mars till 2025. They will need stations established there, which will provide them the proper living conditions. First it will be a small module brought from Earth, in later stages equivalents of Earth houses will be built.

Before, however, it will be possible to build homes using local raw materials, an intermediate stage appears — larger habitable volume brought in a small module: portable architecture.

My goal is to propose a solution in this area, one that will be best suited for conditions on Mars.

Portable architecture will provide large habitable volume and easy transportation to the chosen location at the same time.

I accepted a solution analogous to Earth home with a studio and a workshop. Form of such pneumatic structure will be a result of technical definitions, and its interior will be ergonomic.

Target crew of the base includes eight people of both genders. They will stay on Mars for two years. The whole solution will be based on pneumatic structure, with a high level of modularity maintained.

This solution allows a different look at Earth architecture and will be possible to use on Earth in urgent cases, whan a so-called ”immediate housing” is neccessary.

1.1. Background.

Thanks to technological achievements it is now possible to send humans into space, also for a long-term trip. Polyakov stayed in space for over 430 days. Since 1971 space stations have been orbiting Earth. Onboard astronauts and scientists live and work. One mission lasts from several weeks to several months. During such missions the working-habitable module of a diameter of several meters and length of a dozen or so meters is the only living space for the crew, the only shelter from the vacuum of space and its hostile conditions. Maintaining of a proper environment for human survival is not enough if the missions last for weeks or months. Tightness and constant presence of a small human group cause depression and tensions between the crew members. Extending of the living space, providing a place for isolation and separation of working and living functions are essential for providing physical and psychic comfort of extraterrestrial habitat dwellers. This issue is an architectonic one. This is the moment, when this discipline joins astronautics. Each time a new orbital station is designed, more architectonic solutions are considered and the role of an architect becomes more important.

Vostok was the first space module with one-person crew. In 1961 Gagarin circled the Earth in a small space ship. This short flight did not require complicated equipment necessary for long-term human survival in space. First efficient life support systems were used during several American Apollo Moon missions. Soviet orbital station Salut 1 was the first true space habitat. Later six other Saltut's followed, and each of them was better in terms of technology but also comfort. Salut had several meters of diameter and length of a dozen or so meters. Functions were distributed along such module. Despite the microgravity conditions fake ceiling, walls and floor were made to help humans in their movement among equipment and proper communication with their colleagues on the ground. American Skylab (1973-79) had two levels: one occupied by a laboratory and the other one by quarters.

In the first space stations most of the interior was occupied by scientific equipment and other technical devices. Eventually in the multi-modular Mir station this situation has changed. One of the modules contained only quarters. Thus the gained space allowed to separate two private cabins and more freedom of movement inside. Even better solution was used in the currently orbiting International Space Station ISS. Russian Zvezda and American Nautilus are designed as two residential modules of this station, which will allow seven members of the crew to live and work onboard (up till now there have been 2-3 person groups).

Space shuttle is a substitute of a space station. Shuttle's middeck is a very tight habitat, sent into Earth's orbit for 1-2 weeks, with laboratory-residential modules stored in the cargo bay. Since these missions are quite short, architecture is not very significant here.

1.2. Origins of the issue.

Manned mission to Mars is planned for the third or fourth decade of the century. It is going to last for 2.5 years, including one year spent on the surface of Mars. For this reason providing a safe and comfortable habitat and workplace for the crew is very important. Architecture of this station will be mainly dependent on available technologies and construction solutions. Still socio-psychological and functional factors enforce a deeper analysis of a form of such a structure.

According to the assumptions of the NASA Reference Mission, prepared for the purpose of human exploration of Mars, members of the first crew will dwell in two twin modules of drum-like shape, about 8 m in diameter and of similar length. Five people will spend one year on Mars surface, living in those metal habitats. They will contain mostly living and laboratory space and various stores, for: samples, food, oxygen and fuel. There will not no room for the production of fresh vegetables and fruit. Humans will be completely dependent on the supplies brought from Earth.

Still, research performed within the simulation programs *BIOS-2*, *BIOS-3*, *A.L.S.* have shown, that artificial, closed bio-system allows to produce food in quantities satisfying the crew's need to a large extents, and sufficiently large cultivators of Chlorella algae help in efficient removal of the exhaled carbon dioxide and in providing a sufficient amount of breathing oxygen. Sunlight reaches only through small illuminators.

Members of the Mars Society have created and currently test four analogues of Martian modules complying to the Reference Mission. During simulations in four regions of Earth with conditions similar to Martian ones the functional layout, as well as size and shape of space for individual functions are tested, among others.

A question appears, about what should follow after the NASA Reference Mission is realized in the third/fourth decade.

1.3. Subject.

Architecture is the subject of my study. After the realization of the Reference Mission, which I define as Stage I, an architectonic issue related strictly to us, the architects, will appear. Structures with a foundation on the ground of another planet will appear. It will be a real home for people living on Mars. They will sleep, eat and work there. They will have to feel safe an comfortable there, like at home. Stage II will bring a larger and more comfortable habitable volume, which will have to be transported in a small enclosure of transport module. It turns out that the solution will be analogous to portable architecture used on Earth in similar situations. Stage III will bring larger habitable structures, under large domes or underground, probably made of local materials.

1.4. Goal.

The goal of this master dissertation is to present Stage II, intermediate between small and tight research base and a large planetary base. Instead of two tight metal modules I propose dwelling structure significantly increasing habitable space and providing accommodation for eight people of both genders. Still it is not a large structure requiring a specific ground preparation and infrastructure, but a portable structure, independent from surface unevenness or nearby resources or installations.

My project presents a proposed research station, which is transported to Mars folded and giving a structure of a target shape after proper deployment.

2. Design assumptions.

2.1. 2025 Mission Plan, Stage I.

The Mars Reference Mission was worked out basing on the program called Mars Direct, created by the founders of the Mars Society. It assumes sending humans to Mars for the purpose of conducting various surveys robots can hardly perform. Another assumption is human colonization of Mars. The local conditions are quite similar to Earth and survival of humans in possible there with the use of life support systems. The surface of Mars equals the surface of all Earth's continents. Thus a chance of gaining new lands for humans to inhabit appears.

According to the Reference Mission, first a 45-ton ship is sent to the Red Planet. The ship is to be used for the return to Earth. It is called ERV - Earth Return Vehicle. It is transporting a small nuclear reactor mounted on top of a light, rough-terrain vehicle, automatic installations for chemical reactions with a set of compressors and a pair of rovers (mobile research stations), equipped for scientific surveys. The crew part of the return vehicle includes a life support system, food supply and other objects necessary for the five-person crew during the eight-month return trip to Earth. Upon arrival to Mars the small nuclear reactor produces energy for the chemical installation, which starts to produce methane - the fuel necessary for the return trip. The reaction uses hydrogen from the tanks, brought from Earth and carbon dioxide directly from Martian atmosphere. After three years the configuration of Earth and Mars is again so favorable, that it allows an easy trip of a ship from Earth to Mars. This time the ship carries humans. Five persons arrive in a habitable module. The ship lands near ERV. Linking of the two modules extends habitable surface to two, three-level modules of a diameter of 8 m. Later the crew returns to Earth in the ship, that landed first. Their own ship starts to produce fuel for the crew of the next mission to return to Earth. Each of the modules has 8 m of diameter and the same length. Each of them offers a limited living space, since it also contains various technical and scientific devices. For two and a half years this small habitat will be the only safe living space for five persons. It can induce various problems of sociological and psychological nature. The Reference Mission does not deal with them yet.

2.2. Base development stages.

2.2.1. Stage I

Manned missions to Mars can be launched every three years. Slowly more and more small modules will appear on Mars and a settlement of such metal cylinders, linked with airlocks will appear, enlarging the usage surface of the growing Martian base. Besides, also various scientific equipment and robots can be sent, including ones enabling production based on local resources.

2.2.2. Stage II

These resources will allow construction of habitats for several dozen or more people. Also deployable habitats can be brought from Earth. A transport module 8 m in diameter and height, instead of a return vehicle can contain structures packed in a way portable architecture is packed on Earth. Thus, without using local resources or more complex methods large habitable space can be gained. This is the issue I am trying to solve in this paper.

2.2.3. Stage III

In the future large human settlements may appear on the surface of the Red Planet. They will be covered by great domes or placed underground. Theory assumes that terraforming and change of the atmosphere into one suitable for breathing will last for 100 years. By this time it will be possible to build regular, Earth-like houses on Mars.

2.3. The issue of future extension of Stage II base.

The structure I propose in my project is modular. Multiplication of such system allows the growth of the base according to the arising needs. Subsequent, similar modules can arrive depending on functional demands. Flexibility of the base modules themselves allows them to be used in various ways. The proposed room arrangement bases on analyses of various solutions and seems to be the optimum. If, however, it turns out that later changes are necessary, the technology of the partition walls allows introducing changes of the internal arrangement.

Because the foundation of the base does not require terrain leveling, the base can grow in any direction without the need to perform specialist works on the construction site.

2.4. Modularity

The proposed solution is characterized by a high level of unification of elements, to the furthest possible extent. It allows exchange of functions between the individual domes in case one of them is damaged. Walls of smaller rooms are a subset of walls used for construction of larger rooms. Thus the wall elements can be exchanged and change positions.

2.5. Portable architecture.

The demand for a relatively large surface and functional arrangement became the main factor for the choice of the form of the designed Mars research station. While adapting the technologies of portable architecture to the construction potential of space architecture various concepts were analyzed and grouped in three categories: metal, mixed and pneumatic structures.

3. Function.

Research station will be built for eight-person crew, and equal gender proportion, as well as good relations among the crew are suggested. The crew will include: commander, geologist, astrobiologist, geologist-meteorologist, biologist-agriculturalist, biosphere specialist - majordomo, doctor-psychologist, cook-journalist-architect.

The base will host humans for two years (or even longer), who will be far away from their homes, the Earth, almost like locked in a high-security prison. Designing of such a base should require all the effort to make the stay comfortable, rather like a long holiday. In such conditions all factors able to influence the mood become very important. It should be remembered that even quarrels happened on orbital stations.

3.1. Function analysis

Mars research station has three basic functions: residential, laboratory and agricultural. Each of these functions is autonomous and can be considered separately. Their separation is actually recommended. First - due to safety reasons: various experiments, sometimes dangerous ones, should not reach beyond the laboratory zone. Farming on Mars will be a very specific process, all organisms have to remain under strict control, when, for instance, spread of fungi spores decreases. Construction materials are selected also due to their low level of interaction with living organisms. Still the sterility of the agriculture is recommended due to hygienic reasons. Another criterion influencing the separation of the functions are psychological factors. When the working zone is separated from the habitable one, humans work more efficiently, remaining more focused on the performed tasks, and later rest is more efficient too. These factors are considered in the orbital stations of the new types (multi-modular Mir and ISS). Since resting is related to the presence of green plants and natural environment, the agricultural section has an additional recreation space with deck-chairs. Although briefings on missions and various tasks are a part of the job, the common space in the residential section was chosen as a place where they are organized, since there are good conditions for group meetings here.

Functional analysis forced a division of habitable space into three main parts: residential, working and agricultural. Separation of these functions due to safety reasons suggests placing each of them in an individual, air-tight module. In order to enable easy communication a common junction with an airlock leading to each of them and to the outside is recommended. This passage element of the station does not have to be a large one, but it should be the safest one. It is also a location for a shelter, accessible for evacuation from each module. Also the central module should provide a final support in case of systems failure. It will be equipped with backup power supply and life support systems.

Such discussion leads to a conclusion that three large, portable modules can be packed inside of a small unit of a rigid structure, tested in space conditions. This small module should also contain all the main control devices, A.L.S. (life support), power generator, engine room, switchboxes and terminals.

Each of the functions requires proper rooms and space. The residential module should include private cabins for the crew members, with a bed and a space for individual activity, with a desk and a chair, as well as a closet or a locker for personal belongings. Rooms for hygienic activities, with lavatories and shower are recommended for each crew member. Also a laundry room with drying space should be included. A kitchen with a store and fridge room can be placed next to the mess with space provided both for dining and complete crew meetings. Recreation space and a gym also are located in the residential part. Private cabins are not very large, but common space offers a large surface. It is a solution suggested by results of studies performed during simulations with small groups of people staying together for a long time in separation and during expeditions in polar stations. Strong sensation of separation from the rest of the world creates unity among people and encourages joined activity. Also a small store is provided for servicing purposes and storage of various equipment.

The working part is the main element of the research station. This is a place where various experiments and scientific analyses will be performed. Since diversification of research requires various equipment and sterility, a partition of laboratory space into several labs is required. Alsko a store for data and samples should be provieded. A preparation room leads to the laboratory part - it is necessary to go through it while entering or exiting.

Most of specialized equipment is located in the lab. In case of any equipment failures, repairing is necessary and a small module connected besides offers a space for a workshop. It is also a passage to a garage for Mars Pressurized Vehicle. In order to make the repairs of the vehicle convenient, the workshop's exit lead straight to the garage. The garage is build as a tent and it constitutes an airlock. After the vehicle rolls inside, the tent can be pressurized and repairs of the vehicle can be performed without the necessity of wearing an EVA suit.

The largest of the modules contains agriculture. The larger area is provided for the crop, the larger the coverage of food requirement. It allows to reduce the amount of preserved food brought from Earth. Fresh fruit and vegetables are also healthier and tastier. Eating of meals made of such products will increase physical and mental fitness of the crew members. The agriculture module will include also algae cultivators, producing breathing oxygen for the crew. Chlorella and sorella algae are much more efficient for this purpose, than crop plants and their cultivation is necessary.

Collected vegetables and fruit will be stored in stores and fridge rooms. Also seed stores will be provided.

Honey is a healthy and valuable source of energy an vitamins. It is produced by bees, which will also provide the means of pollination of bush flowers. Thus the agriculture module must also contain a hive.

Communication in each of the modules must be organized in such a way, that partition walls provide ergonomic passages and fast evacuation of the central module is possible in case of an emergency. The central module must include a shelter. The central drum should contain mainly technical features: control devices in the cockpit, technical installations with A.L.S and power generator for the whole base.

3.2. Common features of functional assumption.

Each structural element of the station contains different functions. The central module is the heart of the base. All terminals and the computer controlling the station are located here, as well as rooms for life support system. Workshop function is located in the smallest module of the station. The garage, containing one MPV is the outermost part of the complex. The garage is also an additional exit for humans, since it is also a tight airlock. Three main modules of the station contain (by size): agriculture with garden and hive, residential-recreation space and a lab with medical room. The communication between the modules provides the shortest/optimum way. It bases on the fact that the base entrance is located in the central module. Thus a weary EVA-naut can go directly to the recreation-residential module or go to the lab with the samples. He/she can also rush upstairs to the shelter in order to wait through the solar flare. Along the external walls circumferential corridors are located. They allow a passage through each of the modules without crossing the main space, either residential or laboratory. It is especially important in case the base is extended with new, attached modules. Thus each dominating function is surrounded by a communication route. Simple and clear communication system is efficient in case of emergency evacuation.

4. Architecture.

4.1. Area development plan.

The area, where the research station is located is divided into several zones of different importance. The closest zone A, reaching to about 5m from the station walls is inspected on a daily basis by a responsible crew member. Thus all possible damage or disruptions in the station's functioning are immediately detected and proper remedies can be applied. Another zone, B, reaching about 20 m from the station walls is inspected on a weekly basis, also in order to detect any anomalies in the functioning of the base. The furthest zone, C, is located next to the communication-meteorological tower. The tower is lowered onto that zone for maintenance or assembly purposes. Zone D is contained within zone B.

There are following locations distinguished within the area around the base: parking for quad vehicles, used by the crew for small distance trips and for the MPV, storage area for samples brought from the distance and stored there before being transferred to the lab or the internal stores; waste dump for solid, non-organic waste, transported into orbit once a year and then burned in the atmosphere (MJ: Drogie rozwiźzanie. Czy potrzebne i praktyczne? taki mietnik moe okaza si nieoczekiwanym ródem przydatnych substancji chemicznych. Moe warto przeprowadzi analiz potencjalnego skadu odpadów i metod utylizacji?); area of soil exchange for the agriculture module, being a source of a new soil for the cultivated plants and a place where the used soil is dumped (MJ: Gleba jako temat na prac z chemii rodowiska? biologii?)

Additionally, lighting is located around the base for the zones A and B as well as a system of CCTV cameras for zone A.

4.2. Communication and construction complex.

The planned Mars research station consists of six modules linked by air-tight connections. The central module is a rigid, metal drum with two exits leading outside and three airlocks for the main modules attached to it. These modules are three domes. The smallest one is linked to a small, inflatable workshop, while the workshop is connected to a garage for the MPV. Roads surrounding the complex allow easy maneuvering of the MPV and the quads. Only one typically pedestrian street exists - it leads from the exit of the central module, which is adopted for the use by humans in EVA suits. There is a small platform and stairs leading onto the surface of the planet at front of it.

Three main pneumatic modules are shaped as domes with the diameters of 16, 20 and 24 meters. Two of them have one large window, and the third one has two. Structure of these windows is a special one. They are transparent bevels of the dome sides and due to large surface they provide bright natural sunlight inside. It has a positive influence on the people and allows to decrease the power consumption. The largest transparent surface is placed in the largest dome, containing the crops. With proper placement of the domes around the central drum large amount of sunlight reaches each of the domes and the garden is well-lit throughout the whole day, which stimulates the growth of the crops. Each dome is clamped with Kevlar rigging. These strong ropes clamping the structure are attached to anchors driven into the ground and protecting the domes against overturning. A minimum number of anchoring points was chosen - three - which decreases the weight of the structure and allows a larger transparent surface by beveling the non-rigged surfaces of the domes. Such solution allows beveling at an angle smaller then right angle, which provides better penetration of sunlight inside. Small number of anchoring points allows easy maneuvering of the MPV between them, when the vehicle docs at the central module.

Communication in each of the modules takes place around, along the external walls. Thus all the communication is moved outwards and does not disturb the layout of the interior. Functional rooms are located along these corridors, along the circumference of the opaque dome walls. Entrances to the rooms and passages to the functional areas lead from the rounding corridors. Such arrangement of the communication enables easy orientation in the interior and fast evacuation in case of an emergency. The rooms occupy one half of each dome's surface maximum. Thus open spaces are created, giving a feeling of spaciousness, so important for the crew during their stay on Mars. The largest open space is provided by the agricultural module.

All modules of the base have floor on the same level, which allows carts to move around the whole station. The carts are used for transporting food, laboratory samples, various equipment, etc.

4.3. Open Plan.

All modules are designed according to the Open Plan principle, which means, that internal rooms are not bound to the external walls. It allows free arrangement of the interior. At the same time all the rooms are modular, which means that all residential cabins are identical, and wall panels for residential cabins are identical with wall panels for store rooms in agricultural module (a store is one half of a cabin) and wall panels for laboratory rooms (two residential cabins are 2/3 of a lab). Such base assumptions make future changes of interior arrangement easy, whether it is caused by the "need of a change" or independent reasons, such as damage of one of the three modules and a necessity of adopting an arrangement for a new situation.

4.4. Station elements

4.4.1. Central module

Central module is a drum with rounded ends. Its diameter equals 8 m, its length - 8 m. It is placed vertically on six legs attached to a movable chassis. Thus the bottom part of the module can be rotated and it is possible to position it properly in relation to the Sun after landing, and in the result - it is possible to control the placement of external modules in relation to the cardinal points of the compass. The module has three side lights on the top floor. They let the sunlight in and allow observation of the surrounding.

4.4.2. Agricultural module.

The agricultural module is the largest of the three pneumatic domes. Its diameter equals 24 m. It contains crops to become the source of fresh food for the members of the crew. The plants need light for growth. Good lighting is provided by two large, transparent window surfaces, facing south and north-east. Thus the sunlight penetrates the interior during the whole day. Window bevels make the shape of the module roughly triangular.

4.4.3. Residential module.

The residential module is the second largest dome of a diameter of 20 m. Large window faces south, so the interior is bright and cozy throughout the whole day. Since Mars is located one half of an Astronomical Unit further from the Sun than Earth, sunlight on the surface is not as intensive and no overheating of the interior should occur.

4.4.4. Laboratory module.

The shape of the laboratory module is identical to that of the residential, but the size is smaller, its diameter equals only 16 m. The window of working area faces north-east. The experiments will require mainly artificial lighting here. The window plays a role of a transparent wall, with a view of the surrounding landscape. It has a good influence on psychic comfort.

4.4.5. Workshop.

The workshop is a small, pneumatic square module, with 8 m long sides. Thus it offers four walls for attachment of airlocks leading to other modules or garages. Installation of airtight door is much easier in case of flat walls than of rounded sections of a bowl.

4.4.6. Garage.

The garage for the MPV resembles an ordinary tent. Its layout is rectangular: 12 m long and 8 m wide. The structure is not pneumatic by default. But it is possible to pressurize it, for instance for the purpose of repairing the vehicle without doning the suit. Thus the tent is airtight. It also provides protection against fine dust, capable of penetrating the structural elements of the vehicle, contaminating it and even causing its failure. Since the garage's shape is elongated, it requires more anchoring points, than the domes or the workshop. On the one side a large fastened door is placed. It allows rolling the Martian vehicle inside. On the other side regular, airtight door, leading to the airlock connecting the garage to the workshop is located.

4.5. Division of space in the modules.

4.5.1. Central module.

The central, vertical drum-shaped module is a rigid metal structure. It is a container for the other station elements, folded for the time of transport. After landing on the surface of the Red Planet, automatic deployment and unfolding occurs. The space of the central module is freed then. Three-level drum contains a communication hall with airlocks leading to the outside and to the three modules deployed around. Between the airlocks following facilities are placed in a sequence: stairway to the upper levels, first aid point and a lavatory. The second level contains a shelter, where the crew can hide during solar eruptions, causing increased wave or radiation reaching the surface of the planet. The circular shelter is surrounded by a two-meter wall of water and the access door is made of demron - a material protecting against radiation. Water is the best, available and safe material for protection against solar and cosmic radiation. Additionally, the tanks placed in the walls are a reservoir of drinking water for use during the mission. The upper level contains the cockpit. Station's central computer is located here, and communication with Earth is performed here. Also technical rooms for life support system, control and monitoring are located here. This module is placed on six stabilizing legs and has a rotary chassis, allowing a proper placement of the module in relation to the Sun after the landing. The module has two exit airlocks. One for pedestrian communication, leading to stairs lowered onto the terrain surface, and another one for attaching the MPV. Such solution allows direct access to the surface in EVA suits or passage from the vehicle to the habitat and the opposite, without the suits. In case one of the exit airlocks is damaged, a single one can be used as well. Only the central module is a metal structure. The other elements of the base will be made of flexible materials, allowing their folding during the flight to Mars and their deployment at the destination, after the metal module has safely landed and has been properly oriented in relation to the Sun.

4.5.2. Agricultural module.

Next to the entrance airlock of the agricultural module an additional climatic airlock is located. It is a passage between highly humid atmosphere of the agricultural zone and the rest of the habitat. Three doors lead from the climatic airlock. Two lead to the circumferential corridor along the external wall. This passage gives access to additional rooms to be used as stores, for seedlings preparation etc., - depending on current needs. This corridor leads also to a recreation zone with deckchairs, where one can spend some free time surrounded by greens. Persons entering the agricultural module to work here pass also through another passage with door to a small cloak-room, where one can put on an apron and prepare for work. Also a lavatory and a sink are located here. On the opposite side a freezer is located, used for storage of collected fruits and vegetables before they are taken to the freezer next to the kitchen. The line of the rooms includes also stores for servicing of the farming machine, the hive and the soil. One room is used as a soil laboratory. The remaining, major part of the module's surface is open. In the corner, between the windows, a static element for farming machine is placed. A movable frame is supported by a pole. The machine arm moves along the guide above the crop. This multifunctional machine takes care of all the plants, waters them, scarifies the soil etc. Such solution allows automated farming, and care about the plants, even if the crew is unable to come and work here.

One large soil tank 60 cm tall enables good configuration of crops, thus allowing, for instance crop rotation. Martian soil will be used for farming. Sources describing the composition of the soil state it is quite fertile. A machine, equipped with special pumps is located in the corner of the module and it takes care of soil exchange: one of pipes feeds the soil into the module from the outside, and the other one removes the used soil from the module. Farming area is located in the best-lit part of the module. Three tanks are designed between the farming area and the line of auxiliary rooms: one tank contains water, the second one contains algae, and the last one - compost. Water from the pool is used for crops, part of it evaporates and condenses in steam collectors, to be sent to the drinking water tanks. Algae tank will be filled with chlorella producing oxygen and absorbing the excess carbon dioxide exhaled by humans. Collection of compost allows natural fertilizing of soil. The hive in the corner contains bees used for plant pollination and production of honey. A recreation spot is located at the opposite side. The deckchairs allow the crew to relax among the greens.

4.5.3. Residential module.

Rooms and spaces of the habitat are surrounded by a communication route built according to the open plan principle. The circumferential corridor leads to doors of various rooms: crew cabins, gym, toilet laundry and kitchen space as well as stores. Two side corridors cut through the line of rooms. One of them leads from the open recreation space to an airlock connecting the habitable dome with the central module. The other passage separates groups of cabins, thus shortening the way from the rooms to the common space. Sizes and furniture arrangement of all cabins are the same. There is a small bathroom next to the entrance. Behind the residential rooms there is a laundry and drying room, and further - a gym with a small store. The gym includes various machines for physical exercises the crew has to perform during the mission in order to stay fit. A portion of the gym wall from the window side will be transparent to provide some sunlight. On the second end of the line of rooms the kitchen and the whole store facility are located, as well as a backup room and small store for the recreation room. A well-lit kitchen right next to the large window is equipped as a standard home kitchen. It also has a small pantry and preparation room. The food is stored in free fridges. Because they are located right next to the module entrance, the way of transporting the food to the kitchen from the stores and the garden is shortened. The kitchen part includes a narrow, high table with four cockers attached. A quick meal can be served here. The dining room is a place for joined meals for the whole crew. A large table for eight is also suitable for group briefings. It is located in the best-lit part of the module. The common space has also a separated living room area with comfortable armchairs and sofas, and a reading area. The large space is not divided by any partitions, thus retaining flexibility and it is possible to arrange it according to individual needs during the mission.

4.5.4. Laboratory module.

The working module includes laboratories and a medical room, and also service rooms and a store. While walking along the circumferential corridor one can reach two specialized labs and an open, general purpose lab, also allowing access to the other two labs and the store. Two working places are arranged at the window. Specialized labs are completely separated, tight rooms, with air composition and purity controlled by absolute filters. Each room has three working places and cabinets for equipment and samples. A preparation room includes sinks, clothing cabinets, a bench and a separated toilet. One can prepare for work here and change afterwards. Opposite to the module entrance door a medical room is located, so in case of emergency a way from the other parts of the station would be the shortest possible. The medical room includes a table for patient's examination and an operating table. A sickroom is located at the back of the medical room.

4.5.5. Workshop.

Workshop space is open in order to conduct repairs even for large machines. The cabinets contain equipment and tools. Four workstations allow simultaneous work of several persons. To help in transport of heavy objects (samples, parts of the Mars Pressurized Rover) the workshop is equipped with carts. Various parts of the vehicle and base equipment are repaired here.

4.5.6. Garage.

The garage is able to contain one MPV vehicle, which will be used throughout the mission to move around the terrain, gather samples and perform in situ surveys. The garage will also be a kind of an airlock, since when the vehicle enters, the tent is depressurized, and after the entering and locking, the tent can be filled with air and people can ingress. The garage space allows comfortable parking of Martian vehicle and free embarking and disembarking of its crew.

5. Structure.

Portable architecture on Earth appears in numerous variations. Portable tents, mobile homes on wheels and even floating vessels. But the most interesting are variations of inflatable structures, since they allow larger than usual volumes. They are halls supported on a structure of inflatable beams or halls with a ceiling supported by internal pressure. They can cover even very large surfaces (up to $10000m^2$). Besides pneumatic structures also deployable pantograph or telescopic structures are available. I discuss several structural variations below.

5.1. Structural variations.

5.1.1. Metal structures.

Structure transported from Earth. Ready to be deployed by telescopic deployment or unfolding. Stabilized with legs or poles.

Advantages

- completely produced on Earth
- rigid habitat structure tested in space

Disadvantages

- rigid material — not easily packed (telescopic)
- numerous connections, requiring depressurization protection
- weight limitations — steel structures are heavy, low gain of space in relation to the weight
- is not suitable for farming gardens

5.1.2. Mixed structures.

Structure unfolded in a bellows-like manner, rims or pneumatic beams connected to the coat. Beams and poles anchored in the ground.

Advantages

- rigid beams provide stability of the shape of the structure
- good and easy packing and transport
- relatively small weight of elements enlarging the usable surface
- possibility of adjusting the habitat size

Disadvantages

- complicated assembly
- longitudinal shape enforces reservation of large surface for communication purposes
- necessity of stabilizing of each structural frame

5.1.3. Pneumatic structures.

Inflated pneumatic structure, anchored in the ground, linked to the metal mother module, in which it was transported.

Advantages

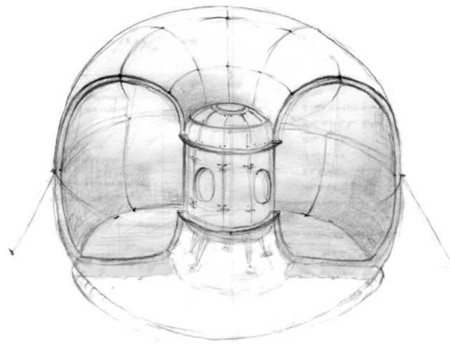
- inflating the structure with air gives it its designed shape
- very easy assembly
- very large gain of usage surface in relation to the weight of the structure

Disadvantages

- necessity of very precise stitching of the coating, with proper materials
- necessity of stabilizing by anchoring in the ground

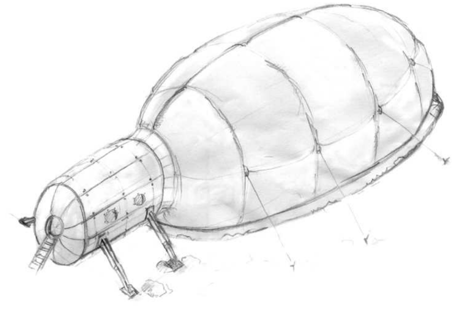
5.1.4. Structure choice.

After an analysis of disadvantages and advantages of the three variations and their comparison it was stated, that pneumatic structures offer the best solution. They provide the largest possible volume with the smallest possible assembly problems. Pneumatic structure can be used to create several different layouts. I have analyzed the following variations:



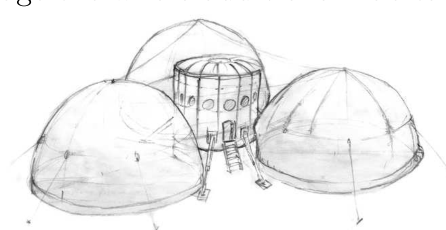
Rys.1. Inflatable torus.

Pneumatic, inflatable torus Such an object provides a high room, which would have to be divided with ceilings, difficult to build. Access airlock has to be located in a flexible wall. Also a problem with resting of the structure on the ground appears. Advantages include large stability of the object, possibility of installation of several passages to the torus and generally large integrity of the interior.



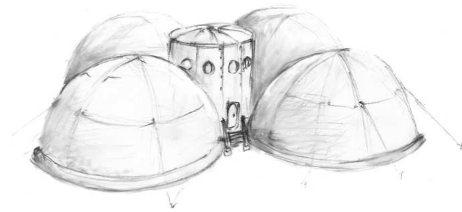
Rys.2. Single coating.

Single pneumatic coating Easy construction of such a structure and easy anchoring in the ground are the most important advantages of this solution. Still a single coating is quite risky — in case of damage the whole additional habitable space is lost.



Rys.3. Three pneumatic coatings.

Three or four pneumatic coatings Relatively large space for arrangement fits the functional division defined in the program. Good protection in case of damaging of any of the coatings — only 1/3 of the habitable space is lost. This solution is a compromise allowing also access to the central module from the outside. It is impossible with four coatings, since passages between them are too narrow.



Rys.4. Four pneumatic coatings.

It turns out that the arrangement of three coatings is the closest to the planned functional layout of the base.

5.2. Central module structure.

The whole module made of steel, many times tested by NASA. Dimensions of the structure, $8m$ of diameter and $8m$ of height comply precisely to the volume of the rocket. External coating is made of thick (about $10cm$) metal sheet and insulation layers. Internal walls are thinner, 3 cm, with insulation and steel couplings between them. Additionally the structure is coated by a demron layer inside — it is a material insulating from cosmic radiation.

5.3. Structure of pneumatic modules.

The largest, agriculture module is completely packed into a space of $9m^3$ (since the wall is $5mm$ thick), while the remaining modules occupy even less space. It means that completely packed modules can be transported inside the bottom part of the central module and immediately attached to the exit. After landing of the central/transport module they are pushed outside. Then they unfold and are inflated. Wall layers are, subsequently: kevlar net, polyimide foil, pyrogel and another polyimide foil. Such composition guarantees tightness and almost bullet-proof durability.

The coating wall structure is supported mainly by the internal pressure, basing on a principle of an inflated balloon, since the external pressure equals 6hPa, while internal pressure equals 1013hPa. Additional elements of the coating, that provide rigidity are beams in and around the window, inflated under very high pressure. The beams are made of polyimide and their layout guarantees remaining of the whole structure standing (only a little distorted), in case any three of the beams are damaged.

Theoretically bullet-proof polyimide foil can be damaged, so for such cases the crew is equipped with glue and patches. This oldest, traditional method of repairing the holes in a bicycle tube can be used also here.

In case of a hole of 5 cm in diameter in the coating, the decompression time equals about 1 hour, mainly due to significant air reserves in the upper part of the round dome. This time can be used for evacuation, closing of the airlocks and securing of the damage.

5.4. Construction details.

5.4.1. Anchoring methods.

Anchoring ropes of the pneumatic structure are fitted with stretching screws to steel rims, attached to the ground. The rims have many holes, so three of them could have fixing pins driven. Anchoring pins are driven into the ground to the depth of $60cm$, and additionally the pins are equipped with teeth, opening after driving into the ground. The anchoring procedure is conducted by the person supervising the base deployment - this person finds suitable place for the base and drives the pin.

5.4.2. Window.

The window is made of two layers of polyimide, with intermediate pressure of 500 hPa between them. Stiffening piles are placed on both sides of the windows. The membranes are stretched onto these piles.

5.4.3. Floor.

To achieve a level floor, during the deployment a rim embracing the whole module is inflated first. After the rim is unfolded, vectran balloons, located under the whole surface of the base floor are inflated. Each balloon is inflated to a volume allowing achieving of a level floor. The inflating process is monitored by a computer. After the level floor is completed it is filled by pumping in of a polymer hardening in low temperatures.

Thus, on an uneven ground a level base floor is achieved.

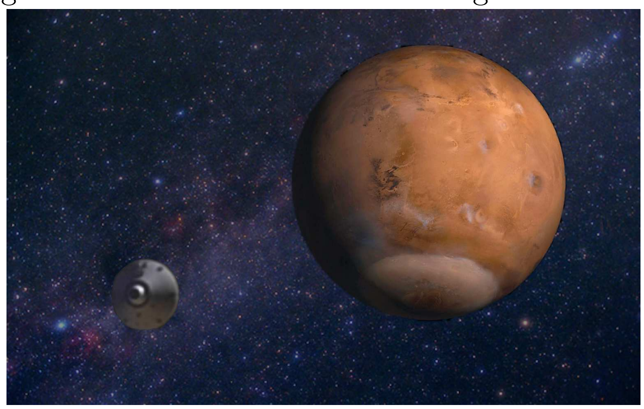
5.4.4. External stairs.

Before unloading, the external stairs are contained inside one of the access airlocks. After the central module lands, the airlock opens and the stairs swivel 180 deg around the sill. Then the stairs unfold to the sides, so the steps are wider than the door itself.

6. Technology.

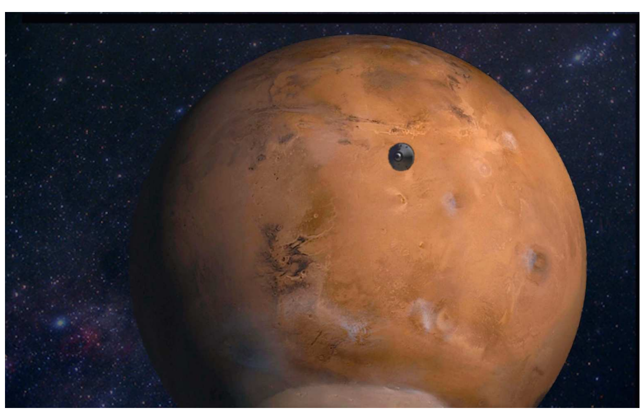
6.1. Method of assembling of the station.

A sequence of ”organization of works at the building site” is shown below”:

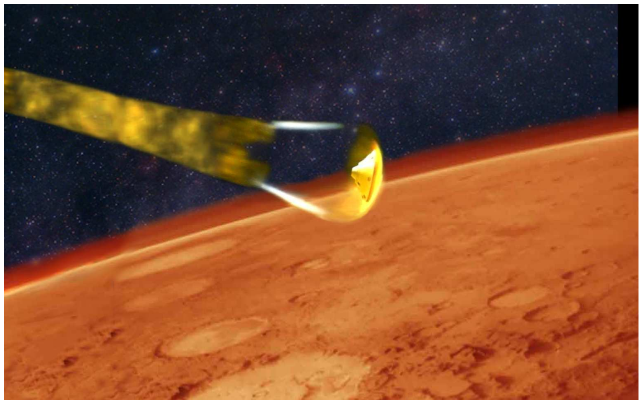


Rys.1. After 7-month journey.

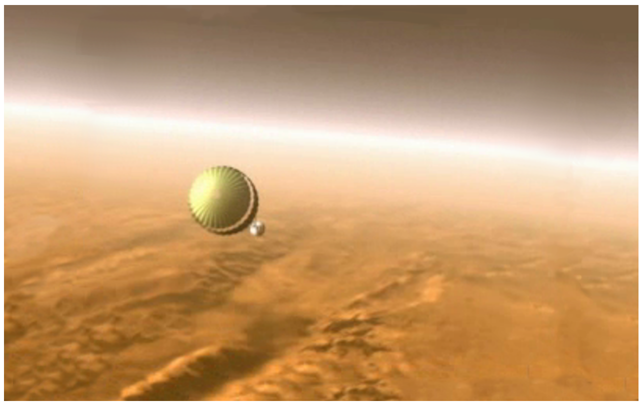
The habitat-container arrives to Mars.



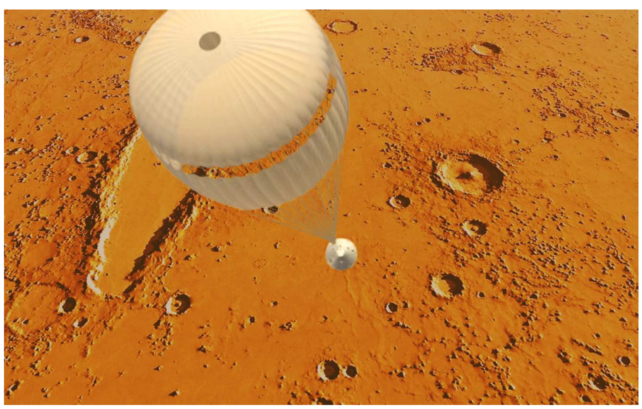
Rys.2. Enters the atmosphere.



Rys.3. Aerobrakes in the atmosphere.

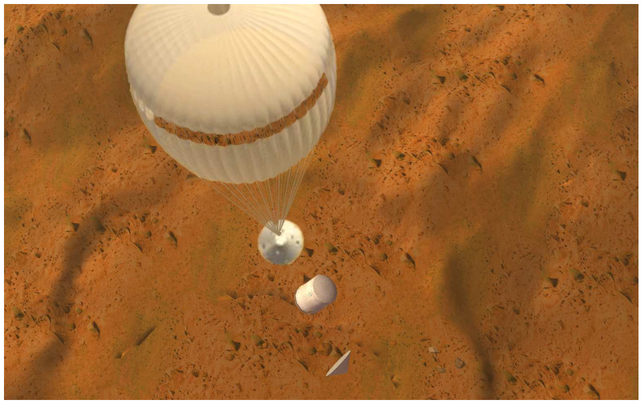


Rys.4. The parachute opens.



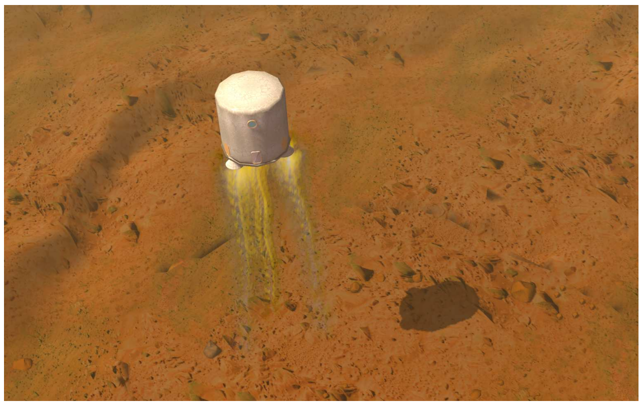
Rys.5. The container drops to the ground.

It drops on the parachute from a height of ca 300 m above the ground level.



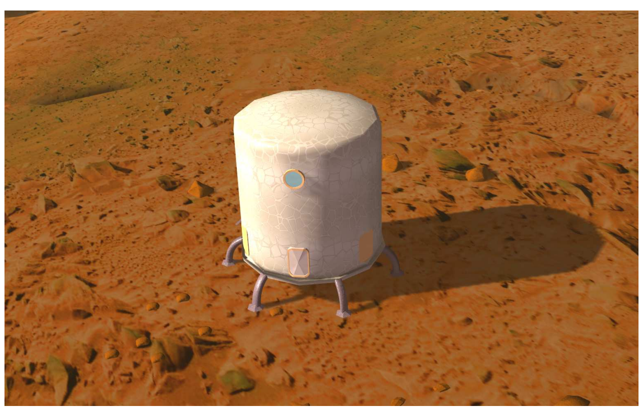
Rys.6. Deployment of the module.

Heatshield opens and the central module, 8 m of diameter and 8 m of height, is freed from the shell. It contains the packed base modules.



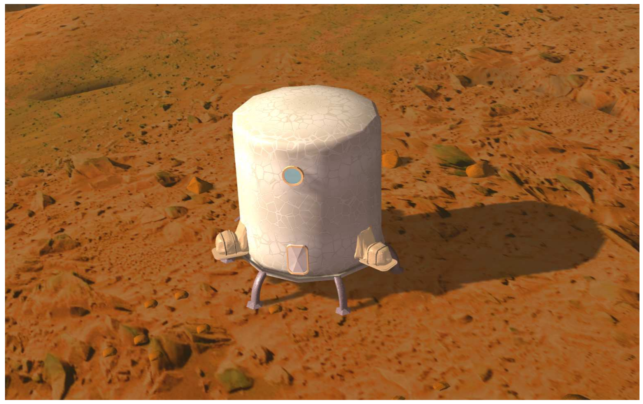
Rys.7. Landing.

The central module stabilizes its drop and brakes above the ground with the use of rocket engines.



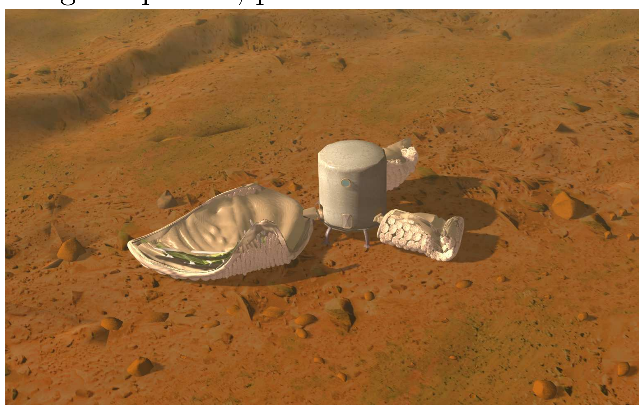
Rys.8. Orientation in relation to cardinal points.

After the landing, the container rotates on its chassis in order to achieve proper orientation in relation to cardinal points.



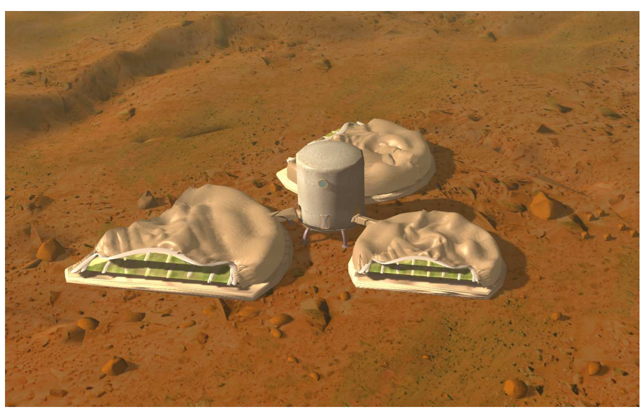
Rys.9. Hatch opening.

The hatches containing the packed, pneumatic modules of the base open.



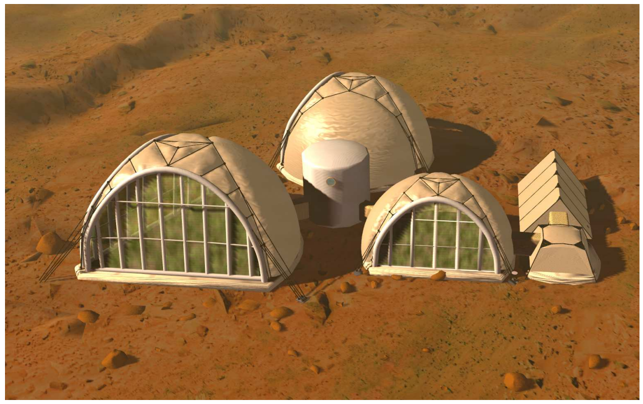
Rys.10. Deployment.

In order for the pneumatic modules to deploy properly first the circumferential rim is inflated.



Rys.11. Floor levelling.

The floor is being leveled with the use of vectran balloons, placed between the floor and the ground (visible on the previous figure). Each balloon is individually inflated to a proper size in order to precisely fill the space between the rocks and the floor surface.



Rys.12. Almost ready.

The $5cm$ thick chamber inside the floor is being pressure-filled with a substance, that after hardening will constitute the floor of the base. The modules are inflated with proper pressure. Automated works are completed at this point. Anchoring in the ground is performed by humans, as well as the assembly of garage and workshop modules.

6.2. Internal installations.

6.2.1. Fire protection installation.

Each pneumatic module contains two complimentary fire extinguishing systems. Depending on the level and type of emergency only one of them is activated.

Inside the installation ducts there is a ventilation duct, in case of fire used as a duct for water steam with concentration of 99

Another fire extinguishing method employs evacuation of the crew from the module with removal of oxygen from it. Pressure adjusting ducts of the modules are used for this purpose. Instead of oxygen, the air-tight module is filled with CO_2. Shells of pneumatic structure are able to withstand short-term exposing to a temperature of 5000K.

The central module contains three fire extinguishing systems: fog extinguishing and sprinkling installation. Extinguishing with carbon dioxide is the last option used here, since it would prevent the crew to stay in the module during the extinguishing. Human presence in a burning central module is, of course, non desirable, however it can not be excluded by means of extinguishing method, since the central module is at the same time the last refuge and communication link between the separate modules.

Additionally, the crew is equipped with small fire extinguishers, located in strategic points of the station.

6.2.2. Ventilation, air conditioning.

All rooms of the station are ventilated and air-conditioned. Installation sections for cabins, laboratories, refrigerator room, workshop, corridors, open spaces and garage are separated. The ventilation works on a principle of blowing air into clean rooms (residential cabin, laboratory, gym, open-plan rooms) and extraction of dirty air from dirty rooms (stores, bathrooms). Additionally, special rooms (laboratories, refrigerator rooms) have bi-directional ventilation and the air is filtered by so called "absolute filters". All installations are routed on the module roofs, vent grilles are located in the ceilings. These rooms have ventilation ducts routed along the window on the floor, blowing the air at the bottom of the windows.

Water circulation also works as a drinking water recycling system. With the temperature risen and a water pool in the agriculture module humidity there is much higher, comparing to the other modules (so the entrance to the agriculture module is equipped with a climatic lock). Water steam collectors gather clean water from the humid air.

Circulating air is constantly filtered in the A.L.S. life- support system on the highest floor of the central module. Dust is collected and air temperature is monitored at the same time. Temperature is also monitored through the heated flooring.

Temperature, humidity and air composition sensors are installed 1.5m above the floor. Three in every module, the sensors communicate wirelessly with the central computer.

Air mixers, which enhance the airflow caused by the ventilation system, are suspended from the top of the modules.

6.2.3. Water circulation inside the modules. Organic waste.

The water supply, containing clean water, is located on the middle floor of the central module.

Water can have four states of contamination: drinking water (clean, boiled), clean water (not boiled), unclean water (coming form the kitchen or laboratory), and contaminated water (coming from the bathrooms and toilets- may contain solid waste).

Clean water, boiled in the A.L.S., is distributed to the kitchen and laboratories. To the bathrooms clean water is distributed.

Unclean water after being filtered in the A.L.S. system goes to the agricultural module, into the water tank and for watering of the plants.

Returning, highly contaminated water is filtered repeatedly in the A.L.S. system, including the use of bacteria and micro-organisms in the filtering process. Solid waste is separated and used as a fertilizer in the agricultural module. Then the water is directed into the agricultural module, as contaminated water.

6.2.4. Inorganic, solid waste.

Apart from solid organic waste, used as fertilizer, the production of solid inorganic waste is also possible. Since this type of waste cannot be recycled, the weight of the base will drop. Because of that, weight losses should be minimized as much as possible. In consequence standard toilet paper for example cannot be used as a several years supply would not fit into the transport module. Instead of toilet paper, pieces of cloth, which can be washed after use, will be used. Notebooks constitute a similar problem- wherever it is possible palmtops and PDAs will replace normal notebooks since the issue of pen and paper is the same as of toilet paper.

Every possible instance of solid waste production should be carefully considered and replaced with a recyclable/multiple-use substitutes.

However, solid waste cannot be completely avoided as it may come from damaged vehicle parts or base equipment. Such waste will be shredded or crushed, packed into bags and stored outside of the base at a suitable place, called the dustbin. Once in a while (every one or two years on average) the accumulated waste will be collected by a ship returning to Earth and thrown into space after the ship leaves the Mars's atmosphere. The waste will burn in the atmosphere.

6.3. Interior technology.

6.3.1. Nuclear reactor, power supply.

The power plant is located on the top floor of the central module, in the engine room. It is a Micro Rapid-L reactor (2x 3x 3 meters) designed in Japan. It was designed for use on the Moon or Mars but, as the authors state, it can also be used on Earth, in regular house basements (provided one is wealthy enough to afford one).

The reactor cannot be the only source of power. The station is equipped with a number of batteries storing the energy that can last for a year in conditions of minimal power consumption. The base also has solar batteries, which can be set up around the base if a need occurs.

6.3.2. Method of cable placement.

All wires and installations run on the ceilings of the housing modules. In the agricultural module a flat grate, on which lighting is supported, is suspended from the cupola and over the agricultural machine, and leads water and electricity to the agricultural machine.

In the airlocks all wires run on the ceiling. From the airlocks the wires run into the engine room and the A.L.S. filters on the top floor of the central module.

6.3.3. Installation of partition walls.

The inner walls are fully portable and interchangeable; a wall can be taken from a housing cabin and installed in the laboratory. The walls are attached to the floor by zip fasteners, which can be installed anywhere on the floor. The walls are fastened together with zip fasteners and so is the whole, with the ceiling.

The wall is a pneumatic inflated construction. On the periphery of a wall panel there are pneumatic beams which are inflated with air under high pressure. The inner surface of a wall panel is composed of a number of chambers filled with Gulfiber acoustic fill. The diameter of the pneumatic beams is 10 cm and the thickness of the inner panel is 5 mm.

A single panel is relatively limp, however, when joined with other panels it becomes stiff.

The ceiling is constructed similarly to the walls, but the inner panel is made of transparent polyimide, thanks to which the rooms are lit from the top.

6.4. External installations.

6.4.1. Radio tower.

A radio-meteorological tower stands near the station. It is built out of steel pipes bolted into ball joints. The tower is anchored to the ground in the same way the base envelopes are.

The tower is equipped with aerials for communication with Earth, radars, lighting and cameras for ground observation, and an apparatus for measuring the composition of the atmosphere and measuring of temperature on different levels above ground.

6.4.2. Lighting and Surveillance

The station is surrounded with sources of light and surveillance cameras. These devices are powered by solar batteries as well as normal batteries. The devices communicate with the base via radio so cables are not needed. When a lamp battery is empty a new one is inserted and the old one is recharged.

The cameras constantly monitor the base surrounding and the video is archived.

7. Interiors.

7.1. Modular system.

The interiors of the base are designed in a way that allows changing for example the residential module into the agricultural module and combining the laboratory with the residential module in case of a failure of one of the main modules. The loss of one of the modules means a radical decrease in living space and the situation becomes and emergency one. The aim of such modular approach is to make the loss of a module only a discomfort and not the cause of a tragedy.

Additionally, the modular system allows refurnishing the base instantly, according to the changing needs of the crew. Probably after two years of use according to its purpose the construction will still be used but for a completely different purpose.

7.2. Interior lighting.

The architectural filling of the interior of the residential module is done by additional lighting, suspended from the cupola (visible on the housing module cross-section). Thanks to this the crew, while eating a meal, will feel like in a large living room, and not like in a well.

Additional lighting of the agricultural module is attached to a flat grate suspended 3m above ground.

In the laboratory each room has its separate ceiling lamp.

A similar solution (energy-saving ceiling lamps) is used in every closed room.

Sunlight, coming through the module windows, is the main source of light. The rooms in the modules also have transparent ceilings made of polyimide for the light to come through.

7.3. Acoustics.

To ensure the acoustic insulation of the walls Gulfiber fill (one globule has a diameter of 3mm), which fill the inner surface of the wall panels, are used. The surface, about 9mm thick, is divided with a number of chambers thanks to which the globules will not pile up inside the wall. A wall insulated in such a way has insulating qualities comparable to a wall made of wood, plaster and with an inner layer of cotton. The advantage of using globules for insulation is that the walls retain their softness and can be easily rolled.

7.4. Greens.

The living room in the housing module is divided with pots with green plants in carts which can be moved to a different location, rearranging the space according to different needs. There are also a few plant pots placed close to the walls, but these will be rarely moved.

8. Safety measures.

8.1. Evacuation route.

The general layout of the base around the central module, which is the evacuation point, makes the evacuation route short. To additionally mark the route, it is lit with faint, energy saving lamps, powered by a separate power source, and with a built in battery that will keep the lamps lit for at least an hour in case of a power failure.

The top floor of the central module is the final place of shelter. There is a cockpit from which communication with Earth can be established, spare spacesuits, a small bathroom, and a supply of canned food, which will allow the crew to survive in extreme conditions until help arrives.

8.2. Shelter.

The shelter on the middle floor, surrounded with layers of water and demron, protects against solar storms. Solar storms are forecasted seven days in advance, which gives the crew a lot of time to prepare for the situation (usually lasting for a few hours). There is a small console in the shelter through which the control room on the upper floor can be controlled.

8.3. Fire protection.

The described in chapter 6.2.1 fire-fighting installation is the main means of protection against fire. Since a fire is the worst inside threat it is not only important to extinguish it as quickly as possible, but also to see that it does not occur.

Polyimide is a fire resistant material and the laboratory is the only room in which fire is meant to be used. The kitchen is equipped with electric cookers. The flame burning in the laboratory has to be under constant supervision. Sparking of electric wires is eliminated to a degree conditioned technologically thanks to wire and fuse screening.

9. Use on Earth

The Martian research station project can be successfully adapted as a prototype research station used on Earth in extreme conditions; weather in high mountains, in the desert or the North or South Pole. Furthermore, through minor functional modifications the construction can be changed into an emergency house that can be dropped from helicopters into areas stuck by natural disasters like, for example, floods.