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MARS-OZ: A DESIGN FOR A SIMULATED MARS BASE IN THE AUSTRALIAN OUTBACK[1]

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Mars Society Australia has developed the design of a simulated Mars base, MARS-OZ, for deployment in outback Australia. MARS-OZ will provide a platform for a diverse range of Mars analogue research in Australia. The simulated base consists of two mobile modules whose dimensions and shape approximate those of horizontally landed bent biconic spacecraft described in an earlier paper. The modules are designed to support field engineering, robotics, architectural, geological, biological and human factors research at varying levels of simulation fidelity. Non-Mars related research can also be accommodated, for example general field geology and biology, and engineering research associated with sustainable, low impact architecture. Crews of up to eight can be accommodated. In addition to its research function, the base also will serve as a centre of space education and outreach activities. The prime site for the MARS-OZ simulated base is located in the northern Flinders Ranges near Arkaroola in South Australia. This region contains many features that provide useful scientific analogues to known or possible past and present conditions on Mars from both a geological and biological perspective. The features will provide a wealth of study opportunities for crews. The very diverse terrain and regolith materials will provide ideal opportunities to field trial a range of equipment, sensors and exploration strategies. If needed, the prime site can be secured from casual visitors, allowing research into human interaction in isolation. Despite its relative isolation, the site is readily accessible by road and air from major Australian centers. This paper provides description of the configuration, design and construction of the proposed facility, its interior layout, equipment and systems fitouts, a detailed cost estimate, and its deployment. We estimate that the deployment of MARS-OZ could occur within nine months of securing funding.

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INTRODUCTION AND BACKGROUND

Mars Society Australia (MSA) in 2001 commenced researching design concepts for an Australian Mars Analogue Research Station (MARS-OZ) adopting horizontally landed bent biconic vehicles as described by Willson and Clarke[1] for the key component modules. Arkaroola in South Australia was selected as the location of the station after assessing a number of areas in Australia as discussed by Clarke[23].

A new simulated Mars base has been considered for Arkaoola as the region offers different and a greater diversity of geology, micro-biology and paleontology that matches or could exist in places on Mars compared to other analogue sites. These sites include the Houghton Crater on Devon Island[4] in the Canadian Arctic, and the Mars Society's MDRS near Hanksville, Utah. Houghton Crater is the site of both the SETI and Mars Institutes' "Mars on Earth" field station and the Mars Society's Flashline analogue station, both these are currently operating independently of each other. The sites have adopted vertical cylinders for their simulated Mars Bases. An advantage of using the alternative long and low horizontally landed bent biconic vehicles at Arkaroola allows the utility of the different designs and layouts to be evaluated and compared.

Horizontally landed bent biconic vehicles have been considered by a range of proposed mission scenarios, in particular those developed in the former Soviet Union by the Energia Group[5] and the International Space University[6] (ISU) that utilized a range of horizontally landed biconic vehicles. A range of biconic landers, some horizontally landed, others vertically, have also been studied in the United States under the auspices of the "Case for Mars"[7 8 9]. These concepts provided a starting point for a MSA crewed Mars lander design and MARS-OZ mission concept, as described elsewhere[10 11]. The missions are based on"Mars Semi-Direct" mission architecture[12], as used by various iterations of NASA's design reference mission[13] (DRM) and others[14].

The modules for the planned simulated base at Arkaroola are to be equivalent to those that would be landed on Mars as in the MARS-OZ mission concept discussed in section 6. As such, the MARS-OZ project at Arkaroola would provide a realistic platform for a wide range of Mars-related field studies for the MSA and its associates.

WHY BUILD A SIMULATED A MARS BASE?

Although there has been extensive research into different Mars mission concepts and considerable experience in long duration space missions, in particular onboard Mir and now the ISS, the issues involved with living and working on Mars have received far less attention. Clarifying these is essential before long duration Mars stays, as contemplated in missions using conjunction-class orbits with 500-600 day surface stay overs, such "Mars Direct"[15] and "Mars Semi-Direct", and Mars bases. A Mars base and components must function for many years. The components must also be adaptable to changing needs as the base grows. There have been a number of important reviews of the key issues in recent years[16 17 18], highlighting a number of operation questions that must be answered early in the design history of any Mars mission.

A simulated Mars base in a well chosen location is a powerful tool in which to explore many of these issues and Mars analogue missions carried out from them[19]. These include living, operating and undertaking research within such a base as well as conducting field exploration work in a Mars like or Mars analogue sites around the base. While conditions are not fully Mars like, they are none the less more extensive, more variable and less controlled than the laboratory and thus provide an intermediate testing ground between laboratory trials and actual deployment. In general three types of testing and research can be undertaken the base.

The first, missions of discovery, involves discovering the broad issues under pining Mars base design and usage in integrated simulated missions in an analogue environment. Examples include the Mars Desert Research Station (MDRS) in Utah[20] or on Devon Island.

The second, missions of opportunity, investigate both the comparison of terrestrial analogues to known or possible Martian environments, past and present, and technologies to study these environments, such as Arkaroola as discussed in section 4 or Devon Island[21].

The third, missions of investigation, test and the trial specific isolated operational aspects or equipment. An example of this is the investigation of methods of integrated data collection and storage[22]. Another example is arranging for controlled isolation from the outside world allowing for social psychological and medical research in the base.

In addition a well-chosen field location can assist in the training of possible crews going to Mars in planetary science. Also selection of crew can be done through studying their human performance and group dynamics in small isolated teams in the base.

Finally, such stations can have an important education and outreach function[23].

As such, this over view assists in setting criteria for the MARS-OZ base design and location. This is covered in the following 2 sections.

THE MARS-OZ PROJECT MISSION STATEMENT AND GOALS.

The reasons for a simulated Mars base discussed above and the quality of Arkaroola as a Mars analogue discussed later in section 4 assist in defining the overall MARS-OZ project. The definitions also provide the baseline design criteria for the structure and the final location in Arkaroola. We suggest the MARS-OZ mission statement as "To explore the issues of living and working on another planet" with the specific goals of:

- To provide planetary scientists access to a Mars like region enabling opportunities to conduct research and training for planetary geologists and astrobiologists in field exploration and their related methodologies;
- To provide geologists, biologists, psychologists, physiologists, engineers, designers and horticulturalists a 'test bed' to research ideas, methodologies and equipment that can operate within the constraints of a base on Mars;
- To empirically test of the design advantages of using bent biconic lifting body shapes as a design basis for Mars bases. In particular, internal utility and accessibility of working spaces, and the mobility of the modules when wheels are attached;
- The trial and demonstration of technologies suitable for environmental low impact self-sustaining mobile structures; and
- To provide an inspirational public outreach vehicle encouraging planetary exploration and the education of public groups and school students into the science and technology of living on another planet.

We can now look at the Arkaroola region and the reasons for its selection as a Mars analogue.

THE ARKAROOLA MARS ANALOGUE REGION

MSA selected the Arkaroola region over five other areas in central Australia (Figure 1) as its prime region for Mars analogue research on the basis of it scientific interest, accessibility, and suitability for a range of engineering and social psychological field research[24 25].

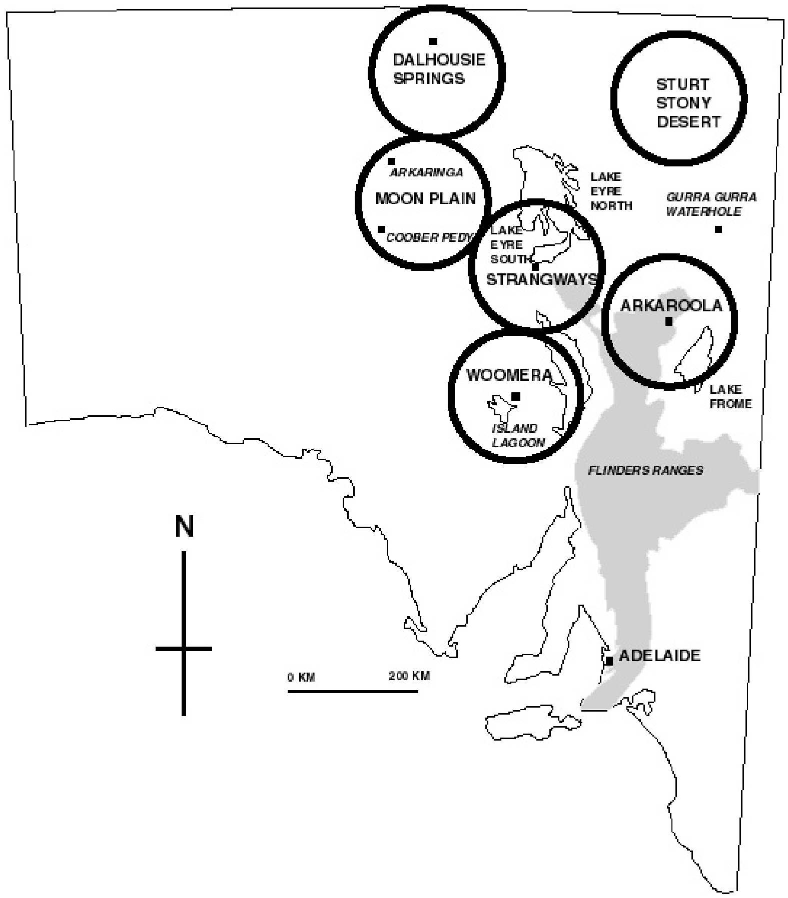

Figure 1. Arkaroola and the five other Mars analogue regions investigated MSA.

Scientifically the region provides an example of studied alluvial, aeolian, lacustrine, and artesian spring sediments and associated duricrusts of the Lake Eyre Basin, adjacent to the dissected uplands of the Flinders Ranges. These offer a range of excellent analogues to equivalent sedimentary successions on Mars and have been extensively studied, both past and present. The geological features differ markedly from those available at Utah and on Devon Island, and thus complement studies at those sites.

The geological units host a range of niches of astrobiological significance, including mound springs, radioactive thermal springs, sinters associated with extinct hydrothermal systems, halophytic and cryptoendolithic organisms in the salt lakes and gibber plains (stony desert pavement) and a range of microbiotic crusts. MSA, and its overseas partners, has commenced collecting baseline data to allow the establishment of a microbiological observatory at Arkaroola. Importantly, the artesian and radioactive hot springs have no parallel at other Mars analogue sites.

The diverse landscape (Figure 2) of the region also allows testing of equipment, such hyperspectral sensors[26], rovers, in diverse arid environments and terrains. Compared with other Mars analogue sites such as Devon Island or Hanksville Utah, which is spatially constrained by land tenure issues, Arkaroola region has few such limits. Traverses of tens of km are possible with only limited interaction with other human activities. Longer-range traverses are possible if use of dirt roads is accepted. Local leaseholders have been enthusiastic supporters of MSA's activities in the region and are hoping for expanded operations in the future.

Figure 2. Aerial view of the eastern margins of the Flinders Ranges and the adjacent Lake Frome Plain. Photo courtesy G. Mann.

In addition to Mars analogue research, the northern Flinders Ranges and its hinterland are of considerable interest to a wide range of general field sciences, including geology, biology, ecology, soil science, hydrogeology and paleontology.

THE MARS-OZ SITE

The preferred site for the MARS-OZ simulated base lies on the Arkaroola lease, Australia's first and largest private nature preserve. The Sprigg family who run the property have a long history of supporting scientific research and ecotourism. They are supportive of the establishment of a Mars analogue facility and the many visitors to the region provide an excellent opportunity for outreach[27]. Arkaroola is eight hours by road north of Adelaide. In an emergency the all weather airstrip at Balcanoona would permit air evacuation by the Royal Flying Doctor Service, the same airstrip can also be used by charter operators.

The site itself (Figure 3), subject to environmental and native title clearance, lies on the eastern margin of the Flinders Ranges. It is located in a narrow belt of low rolling hills dissected by small gullies between the fans of the Lake Frome Plain and the eastern margin of the Flinders ranges. The bedrock consists of Proterozoic Wooltana basalts cut by numerous veins of quartz-hematite breccia. Some of the hills were mantled by residual caps of transported pebbles and cobbles of two different ages; a quartz-rich lithology formed by Cretaceous near shore deposits and a lithic gravel of relict Pleistocene fans. Several meters of basalt saprolite are preserved under the gravel caps. The soils are red brown and swelling, and are mantled with an amour of angular cobble to pebble-sized gibbers. Vegetation is sparse, with scattered small bushes and almost no grass.

Figure 3. View southwest over the proposed MARS-OZ site.

The site is readily accessible by unsealed track from both Arkaroola and the main highway to the east. Some upgrading of the track from the east would be required to allow the large MARS-OZ modules to be brought in. Despite this ease of access, security can be easily maintained by means of gates. This would allow complete isolation from the outside world, if required for research, for example social psychology.

BASE DESIGN

The design of the Mars base required the combined inputs from a detailed workable Mars mission vehicle concept design and the specific aims and goals for a Mars surface simulation discussed in section 3.

A family of Mars landers has been covered in detail by Willson and Clarke[28]. The mission concept employs 3 vehicles and a Habitat vehicle (or Hab), the Cargo vehicle both of which land and a Mars Transfer Vehicle that remains in orbit. The Cargo vehicle has a separable forward section housing a Mars Ascent Vehicle with an in-situ fuel processing plant. The rear section is a garage with a pressurized rover, multi-port adaptors, flexible airlocks and other cargo.

In brief, the Hab and Cargo vehicles travel separately to mars but land near to each other. The crew walk or drive in a lightweight open rover from the Hab to the Cargo vehicle. They extract the pressurized rover from the garage. Wheels are attached to the garage section and it is detached from the forward section of the Cargo vehicle. The crew in the pressurized rover tow the garage to the Hab. Here they unload the adaptor module and flexible extension airlock and assemble all the components to form a Mars base. This assembly process (Figure 4) can be tested during the assembly of the MARS-OZ base in Arkaroola.

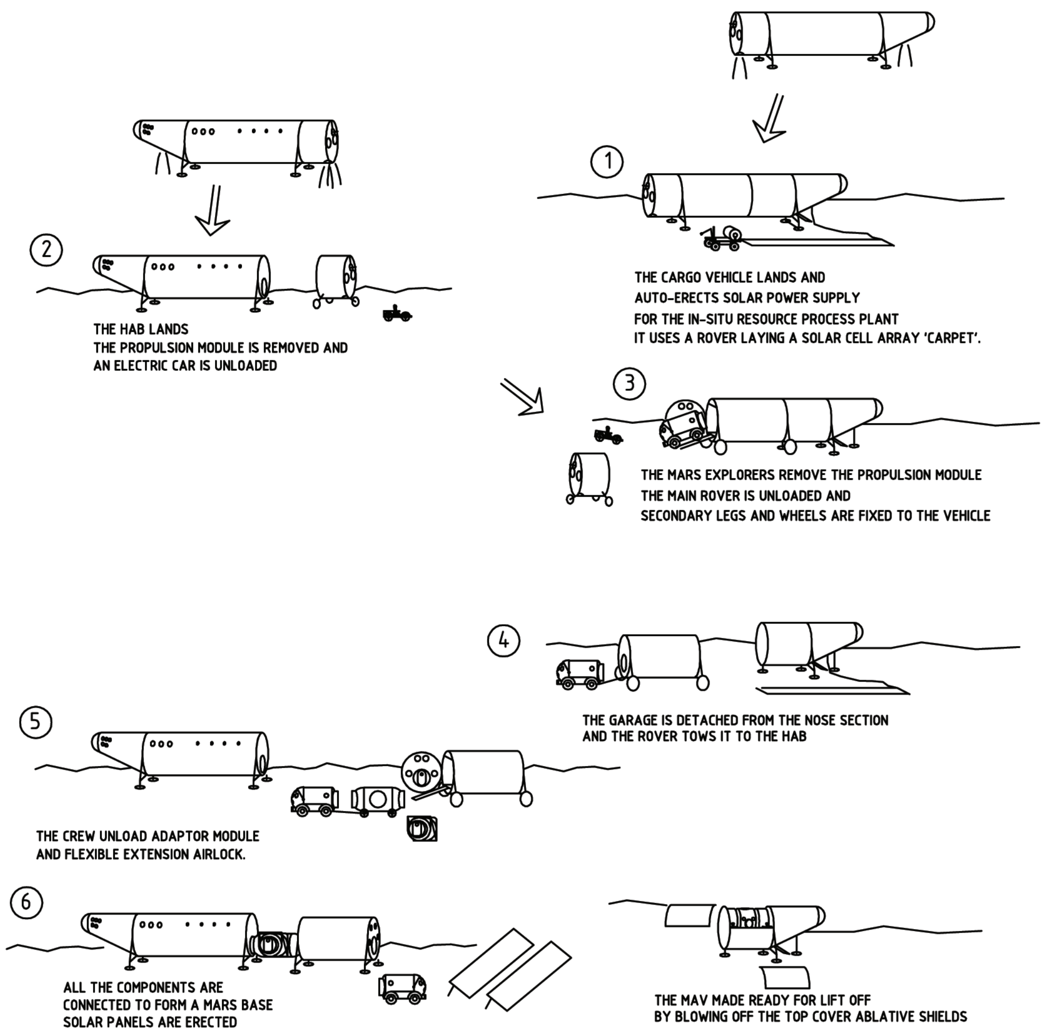

Figure 4. The Assembly of the base on Mars.

The crew return to Earth via the Mars Ascent vehicle that blasts off from the Cargo vehicle forward section and ascends to a low orbit around Mars, docking with the Mars Transfer Vehicle. This then transports the crew home to Earth. The crew land on Earth in a small landing capsule.

The vehicle concept is based around modules of nominally 62 tonnes utilizing horizontally landed bent biconic vehicles. These modules offer considerable advantages over other vehicle shapes. In brief, these are:

- They have a low deceleration g loading, good maneuverability during Mars entry providing accurate placement of payloads on the surface compared to other Mars landers;
- They have superior cargo carrying capacity (especially with respect to long bulky items), easier loading, unloading, entry and egress. The configuration also offers the most growth potential through by simply lengthening the module;
- The low shape makes easier provision of radiation protection using regolith materials, either through burial or erection of a regolith-covered roof; and,
- Their long low shape facilitates, with the addition of wheels, towing and re-positioning on the surface of Mars. A number of modules can be connected via connecting them to multi-port adaptors creating a growing Mars base.

These design advantages and the MARS-OZ mission goals form the 'driver' for the simulated base geometry, internal architecture and structural design covered in the following sections.

THE MARS-OZ SIMULATED BASE ARCHITECTURAL ELEMENTS

We propose that the simulated Mars base to consist of the two landing vehicles, the Hab and Cargo vehicle as shown in Figure 5. These are the horizontally landed bent biconic vehicle shapes 18 meters long by 4.7 meters in diameter. For the purposes of the simulation base, the Cargo vehicle will be made separable with a forward section and rear 'garage' section carrying the rover. The forward section will not have a 'chemical' processing plant and 'Mars Ascent Vehicle', although plywood mock ups of these components can be made, if needed. Instead this section will house two diesel generators, and fuel. The rear garage section is equipped with detachable wheels, as would the real vehicle on Mars, and can be towed by the rover to the Hab section (Figure 5). The base will also employ the adaptor module with multiple docking hatches and a flexible extension airlock.

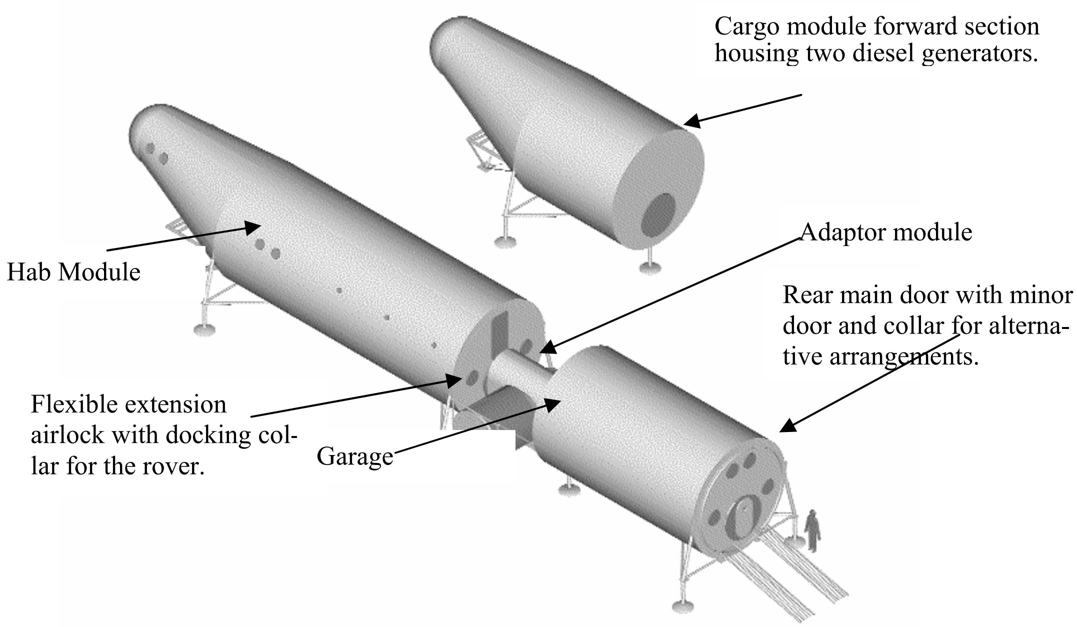

Figure 5. The MARS-OZ base configuration. Showing habitat module (left), adaptor and airlock module (centre) garage module (bottom left) and power and simulated ascent stage housing (top).

As discussed, a fundamental part of the simulated base experience is to trial this assembly process as realistically as possible. This includes 'timing' the process and ascertaining the most efficient manpower and vehicle requirements to achieve the best result.

Once the simulated base is deployed the assumed vehicle dimensions, diameter and the internal architecture can be trialed for long-term living and working utility.

Hab Module Internal Detail

The internal architecture layout has been driven by a range of issues, including dust management, people traffic control, room accessibility, and acoustic management. Experience gained from living in the Mars Desert Research Station during Expedition One provided an important source of practical data[29]. For example, dust management and suppression is major issue in Mars exploration[30] as it is in any outback facility in Australia, and its control has been a major design consideration. In addition the base configuration is a compromise between the Hab (Figure 6) being a 'stand alone' structure and it being connected to the Garage or other modules.[31]

The crew enter the base through the main airlock/adaptor module. They clean their suits in the airlock. The crew can move into the suit storage vestibule at the rear of the Hab on the lower deck and remove their suits. Further cleaning may occur in this area. The crew can then step into the wet room and shower and wash before moving into the exercise/medical room. Stairs in this area provide access to the upper deck. The laboratory is in the forward part of the lower deck of the Hab. These working areas are kept separate from the upper deck living areas. The medical area is kept on the lower deck to facilitate easy access in an emergency.

The upper deck living area includes the galley and mess area, control station (cockpit) and individual bedrooms at the rear. The upper deck bedrooms are located far as possible from the lab to mitigate noise. The design provides up to eight individual cabins to allow for evaluation of crew sizes other than the four of the MARS-OZ concept mission[32]. The cockpit would be converted to a meeting room and office area after landing. A second stairwell connects the control station to the forward end of the lab, eliminating work traffic moving through the galley and mess while providing alternate access between decks in an emergency. The stairwell also provides emergency outside access and on a real Mars lander could be sealed off as a second airlock, if needed.

An important feature of the upper level plan is the configurability of the sleeping quarters. The rooms in this area are designed using a hinged, modular construction system. This allows the layout to be easily converted according to the needs of individual crews from an arrangement of eight cabins along a central corridor to either a smaller number of rooms with an enlarged general living area, or to just a single, large open space. The sleeping quarter layout could be customized for specific missions, and crew would have the option of changing the configuration during the day or during a mission if they chose.

Design of the interior aims to optimize the layout and arrangement of various functions within the limited confines of the Hab. Interior spaces and fittings are designed to be partially reconfigurable to accommodate a variety of tasks and functions depending on changing requirements. For example, the central medical facility and exercise area is planned as a flexible area with deployable equipment. The upper flight deck may also be freely reconfigured to suit various requirements including a meeting area, lounge or theatre.

The design of the upper deck aims to provide a functional layout for living and sleeping that offers a sense of spaciousness and can be readily adapted and personalized to mitigate the psychological effects of living in a confined space over long periods of time. A partition system is proposed that can unfold to define the required number of individual sleeping/working bays, or stowed to provide more open living space. Foldout partitions balance the need for intimate and private space with the need for spatial flexibility. They offer the opportunity to create a larger space to relieve feelings of confinement, to accommodate larger group activities, or simply to allow less constricted movement through the cabin.

This configurability has been included to allow for undertake comparative studies of different crew sizes and of different possible living quarter arrangements. It is also a response to the physically confined nature of the habitat interior. Living together in confined spaces such as this for extended periods of time can a degree of psychological stress on crews. MARS-OZ crews will be able to enlarge their living area during the day by folding away unused sleeping cubicles, if desired. Alternatively, given that personal space in close quarters is highly prized, used sleeping spaces when the base is occupied by smaller crews can be stowed for increased open areas, reconfigured for storage. A third option is less, but larger sleeping space for use by crew members who are couples.

Other features that will enhance the feeling of interior spaciousness include the use of color, fold-away furniture; careful positioning of window openings and virtual space will also contribute to a sense of openness. This adaptability will be highly desirable on an actual Mars base module. How to best to achieve this reconfigurability within the constraints of the MARS-OZ simulated base modules is the subject of ongoing research. Aspects of different internal configurations are illustrated in are illustrated in Figure 7.

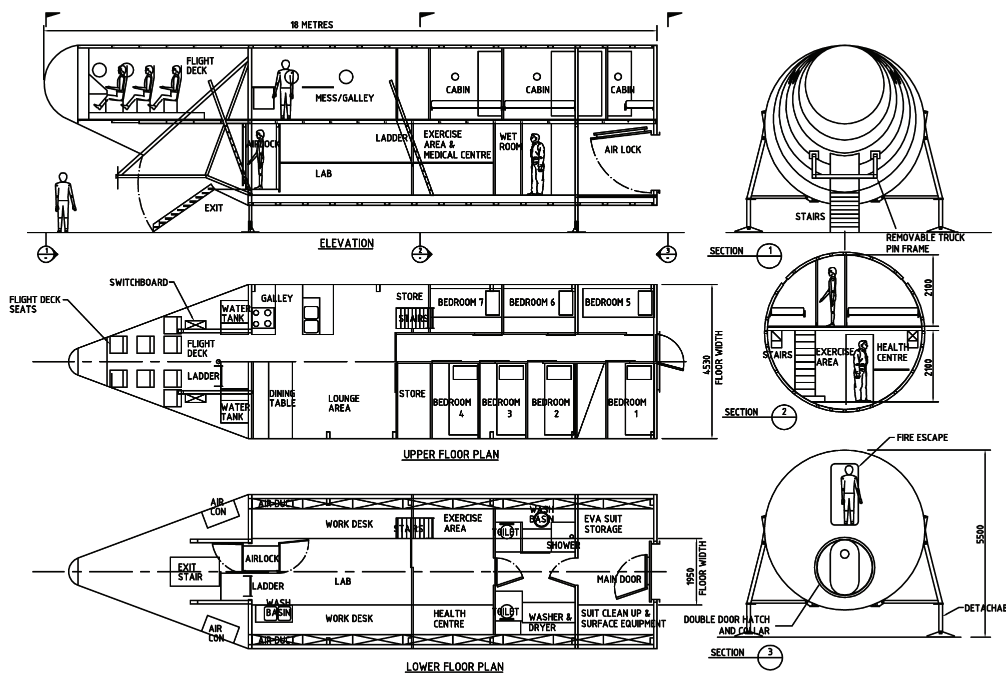

Figure 6. Hab structure and interior.

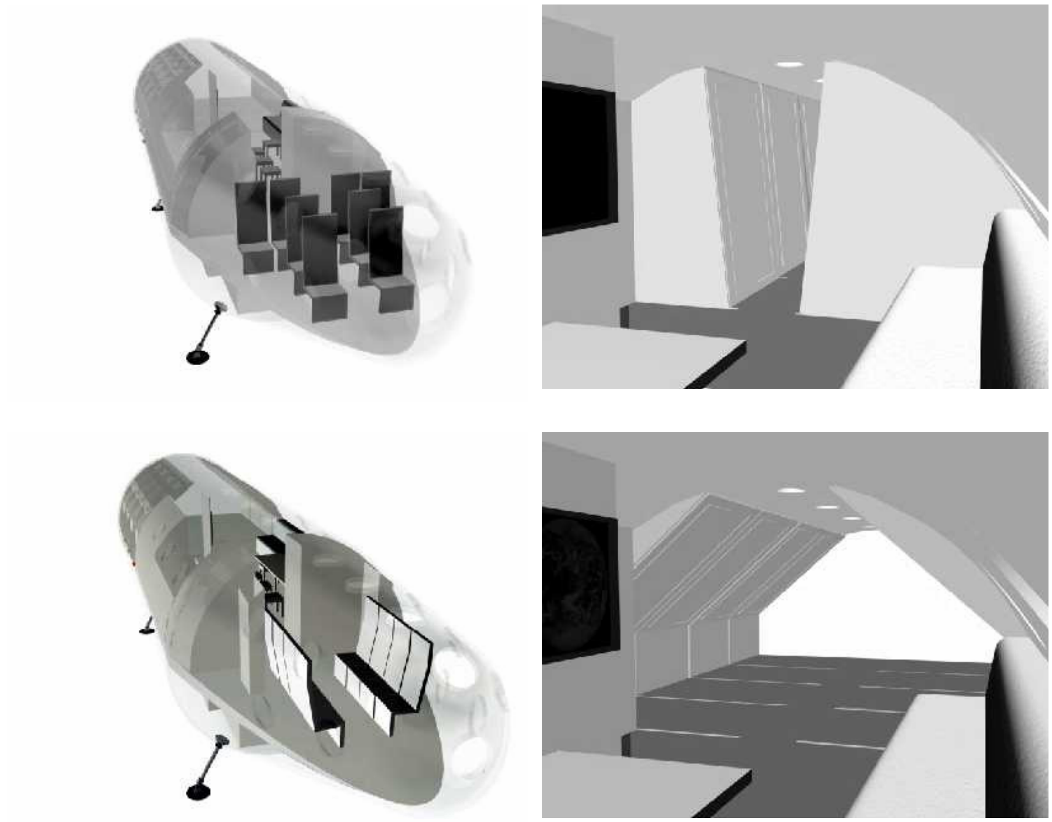

Figure 7. Interior schematics of the MARS-OZ Hab module showing representative different configurations allowable with movable bulkheads and fittings as developed by Kirtsen Thompson Architects, Melbourne. TOP LEFT: control cabin in "cockpit" configuration. BOTTOM LEFT: control cabin in "conference" configuration. TOP RIGHT: View aft on upper deck showing all eight sleeping cabins deployed. BOTTOM RIGHT: view aft showing all sleeping cabins folded away.

Cargo Module Detail

The cargo module is designed in two sections. These are transported to site as a single unit the shape of the bent biconic lander. On site these come apart into the forward section (containing generators, fuel and a mock up ascent stage) and the garage module, containing the rover, collapsed adaptor module, a flexible extension airlock and other cargo (Figures 8 and 9). The rover is at present being constructed in Western Australia as the 'Starchaser Marsupial rover' by the MSA.

Separating the garage from the forward section involves the following procedure:

1) The Cargo vehicle is jacked;
2) The wheels are attached to the rear landing legs and under the garage at the join to the forward section;
3) Two additional support legs are attached to the forward section. This ensures the forward section is supported after being detached from the garage;

4) One section is then jacked to relieve the load between the two halves;
5) The joining bolts, adjacent to the horizontal stringers, are removed and the halves separated. On Mars these would likely be explosive bolts, detonated by pressing a button. Our simulation will require the bolts to be undone by hand.

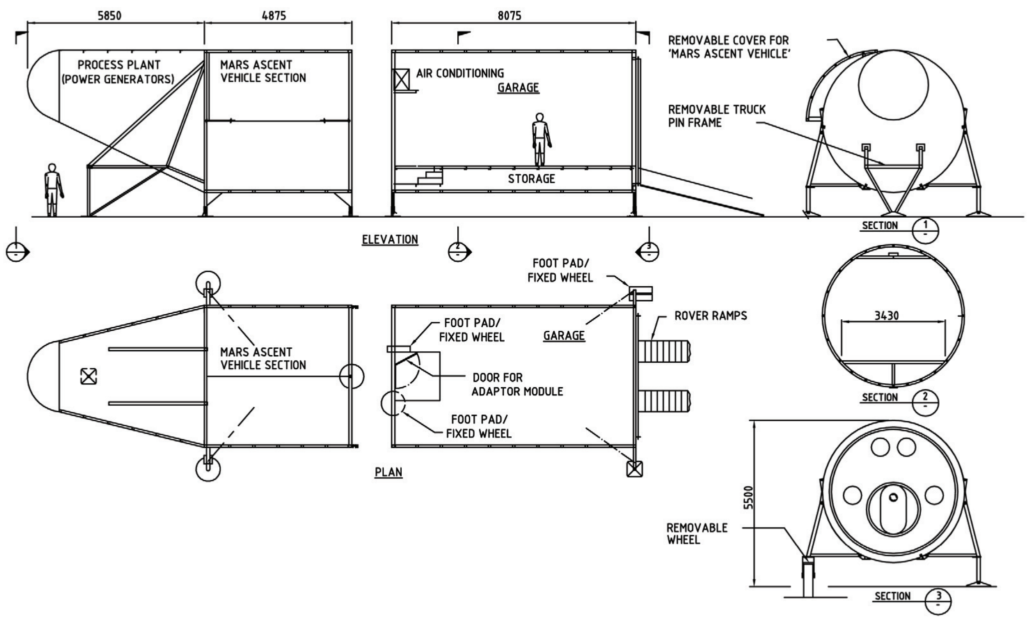

Figure 8. Cargo module showing forward section (housing generator and mock up ascent stage) and detachable garage module.

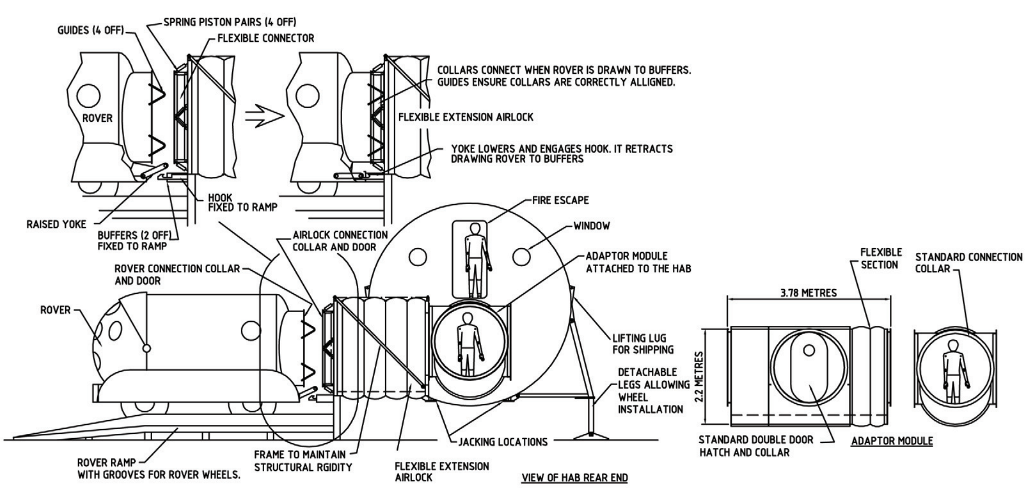

Figure 9. View of Hab rear, adaptor module and flexible extension airlock and rover docking system.

Once separated, the forward section of the cargo vehicle would be located near the base and used for storage and as a generator house. On site at Arkaroola this might be within 100 m. On Mars the ascent stage would have to be parked up to 1 km away to ensure safety in the event of an explosion.

Assembling the base involves connecting the Hab to the Garage section. This process employs the adaptor module. It is constructed from aluminum, weighs 200 kg and is fixed onto a small trolley. This enables two or three people to roll it out of the Garage and bolt one end to the Hab tail door docking collar ring. A small winch would be required to assist rolling it down the Garage ramp. The adaptor module is a connection tube with hatches at each end and on the sides. The garage end of the adaptor module has a flexible section to cater for any misalignment between the structures. The garage is pushed by the rover so to line up its door docking collar ring as near as possible to the adaptor module flexible end. This connection is bolted together (Figure 9).

Finally, the flexible extension airlock, made flexible to reduce its storage space in the garage, is bolted one of the adaptor module side hatches. The air lock does require a small support trestle to prevent the airlock sagging when loaded with people.

A key design feature is the hatches. These are a double door system consisting of a small door for normal entry fixed to a 1.6 meter diameter hinged door fixed to a collar ring. All hatches used on the Hab, Garage, adaptor and flexible extension airlock modules are of matching design, allowing experimentation in alternative arrangements. For example, the flexible extension airlock can be fixed to the garage or the rear of Hab.

In addition the flexible extension airlock hatch can be docked to a matching hatch on the rear of the rover. When this occurs the crew can move between the Hab and Rover without climbing into space suits and stepping outside. The engineering concept for this detail is shown in Figure 9.

In brief, the rover docking system employs a ramp fixed to the airlock, a flexible connection tube on the airlock, hook and a yoke on the rover.

The rover backs up the ramp and lowers its yoke to engage the ramp hook. The ramp ensures the rover is reasonably aligned with the airlock and it is fixed to the airlock frame. The ramp also ensures the loads imparted by the rover are kept separate from the remaining structure. Once engaged the yoke is retracted locking the rover into the ramp buffers. The action also allows collar guides on the rover to force the airlock collar into alignment with the rover collar when the connection is made. The airlock collar ring is attached to a short flexible tube which is held in place by 4 sets of spring loaded pairs of pistons. This enables the airlock collar system to be self supporting but flexible to cater for minor misalignment between the rover and airlock. Finally in a real base latches in the rover collar would engage the airlock collar to provide an air-tight seal. The last mechanism is not required on the simulated base as it is not pressurized.

The ‘yoke and hook’ system has been used by the author for latching raised shiploader booms. It locks the rover to prevent it from pushed away by the pressurized connection or accidentally driven away while still attached to the airlock. The design ensures it can be easily released again when the rover drives away.

BASE CONSTRUCTION, SYSTEMS AND DEPLOYMENT

The simulated Mars base has been designed to approximate the possible dimensions of a future base where possible. The Hab mass is estimated at 22 tonnes and Cargo module mass estimated at 14 tonnes. Air will not recycled, the structure will be mild steel instead of aluminum alloy and, at least initially, its power supply is to be provided by diesel generators. However it will recycle water, minimize power usage and have systems monitored remotely transmitted via an Internet satellite link.

Structure

The module structure will consist of an internal 3mm mild steel plate within 75 mm RHS hoop frames and 50mm RHS stringers. The outer cladding is panel rib roofing steel. Insulation is sandwiched between the inner steel and outer cladding. The floors are of 100mm deep girts clad with 20 mm thick floor ply with covered with vinyl. The room walls are aluminum sheets riveted to 50 mm RHS steel frames. Insulation is sandwiched between the walls. The interior walls are to be re-configurable to test different room arrangements and furnishing.

Safety

The simulated base must meet statutory requirements for noise, temperature, and ventilation. Fire is a major risk in any enclosed structure, and where possible the facility is to be constructed of non-inflammable or fire retardant materials. The MAR-OZ Hab module is also provided with three exits, two on the lower deck (the forward and rear "airlocks", and an upper deck emergency exit at the rear. The two stairways, located centre and aft should allow access to at least one exit at all times, not matter where a fire is located. The garage module has two exits, forward and aft. While provision of a sprinkler or similar fire protection system may be impractical, each compartment should be equipped with a fire extinguisher. We envisage each compartment being fitted with smoke or heat sensors.

Furnishing

We expect people to live in the base for long periods of time and human factors research to be conducted, trialing the room layouts and furnishings. Chairs, tables, beds and storage lockers are to be made from aluminum sheets and thin walled furniture steel. The base control cables, power cables, computer network cables, water piping and air conditioning ducts are stowed on cable ladders in main ducts located under the mid floor on each side of the lower deck section. The cable ladders can be access via removable panels on the ducts.

Air Conditioning

The structure is to be made as airtight as practical. This will allow for the possible inclusion of air recycling equipment at a later stage. Until then, air is drawn in from the outside through the nose section via 2 air conditioning units and ducted throughout the Hab. The adaptor module and flexible extension airlock is connected to this system. The garage section is to have its own air conditioning unit. The air conditioning system is designed to maintain the base at a comfortable temperature during the worse case 50º C summer temperatures occasionally achieved at Arkaroola. We expect the air conditioning units in the Hab to use up to 14 kW power for cooling during the hot periods. The Hab wall insulation has been designed for this purpose.

Water Recycling

Unlike air, the water is to be recycled. It is supplied from fresh water and 'grey' water tanks. The kitchen is to have a fresh water outlet for drinking, a cold 'grey' water outlet and a hot 'grey' water outlet. The fresh water is to be recycled to 'grey' water via a reverse osmosis water recycler and an UV sterilizer. Most of the piping will be in the form of plastic hoses and is designed to be easily altered to test alternative circuits. The system does not recycle urine because an incinerating toilet is specified to consume human waste.

The overall system is shown in Figure 10. The air conditioning, sanitary and water recycling system is to be part of the goal for the demonstration of technologies suitable for environmental low impact self-sustaining mobile structures. The aim being to provide a package of power, sanitary, water and services for mobile structures used by construction camps, emergency services and the army.

Power supply

The proposed power supply is to be 2 x 10 kW 240V diesel generators housed in the forward section of the Cargo vehicle. The base power system is to have rectifiers and batteries available to add on a solar cell generator. This will provide for all electric system, including heating, cooling, cooking, and waste disposal. Multiple power outlets will be provided for each compartment, especially in the working areas. We envisage that solar cells might be gradually phased in over time.

Instrumentation

We propose that the services and power supply are to have monitoring instrumentation that measures:

- The power usage;
- The internal and external temperatures;
- Air and water flow rates;
- Tank levels; and
- Humidity and CO_2.

The purpose of the instrumentation is for the monitoring interior environment and for improving of the efficiency of the water recycling and power system. The data will be sent to the base computer that is connected to the satellite link.

Communications and Data

We proposed to provide a satellite and Internet link between the base and research establishments. The link would allow video communication and down loaded data from the monitoring instruments to be displayed at any research centre in the world and to a proposed interpretation centre located at the Arkaroola village. The interpretation centre is for the 'Public outreach' and is discussed in section 8.10.

We suggest this can be achieved with the following software and hardware:

- A SCADA (Supervisory Control and Data Acquisition) software for the data acquisition and display at the base and Winc software provided at the research offices of the for displaying the information;

- An Israeli designed Gilat 360e satellite modem providing uplink speeds of 110 Kbytes and down link speeds of 400 Kbps with a 1.2 m offset dish for the satellite communications system; and,
- A standard PC, a PLC to read data from the monitoring instrumentation, a video capture card for the video cameras, and five video cameras with radio link. The video cameras would be located in and around the Hab and Garage.

This hardware and software provides the best quality for the lowest cost data storage and communications link via the Internet. The system is also shown in Figure 11.

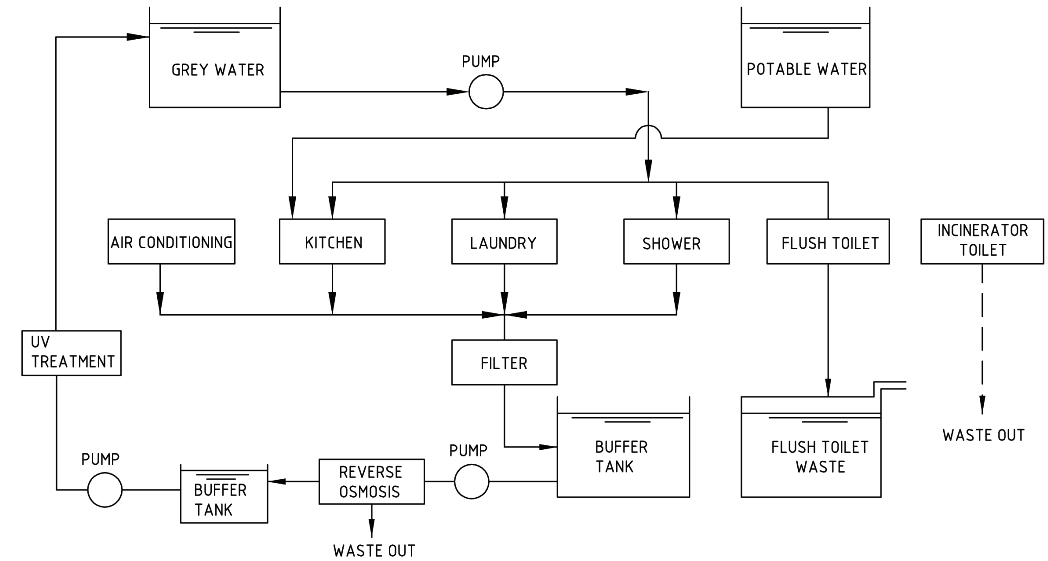

Figure 10. Diagram of the water recycling system

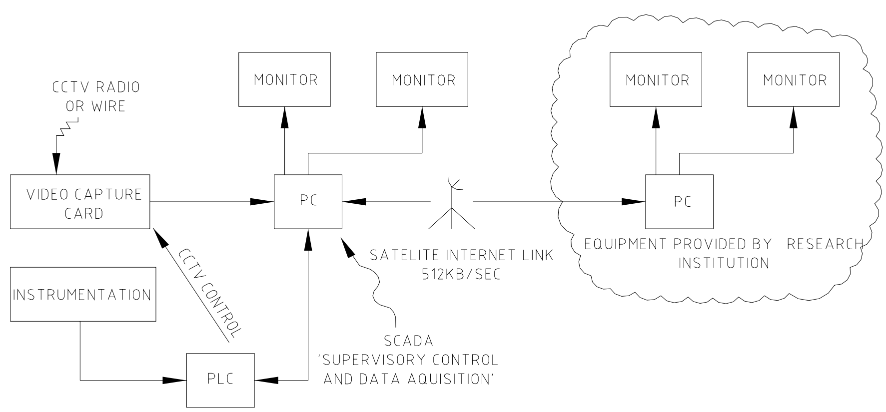

Figure 11. Diagram of the data collection and communication system

Transport

The simulated Hab and Cargo modules are to be transportable in two separable units behind prime movers. We do not intended that the modules are moved regularly, but they can be moved on rare occasions to different locations. In addition the modules can be fitted out and checked at an industrial site before transported. To achieve this a removable tow pin and wheel frame is employed.

The removable tow pin is located on a frame under the nose section of each unit. This enables the modules to be hooked up to a prime mover. A detachable 2 x 9 tonne axle wheel frame supports the rear end of the module. The frame is bolted to cleats on the back end of the module.

The transport set up (Figure 12) allows 300mm clearance to the road, combined with the module width of 4.7 meters giving an overall height of 5 meters. The height clearance is higher than the highest Australian legal limit of 4.6 meters on Australian roads but low enough to pass under bridges and overpasses on the main Australian highways. The transport height and width triggers the need for a structural certificate and a permit from local transport authorities. The vehicle will require an escort but not a police escort.

The low clearance to the ground is suitable for the main highways but will be an issue when being moved on the rough tracks at Arkaroola. When this occurs the rear end of the module is jacked up to 600 mm clearance to the ground and the wheel frame lowered to new matching bolt holes on the cleats. The vehicle does not pass under objects while being moved in these areas. Some minor road works may be required.

Finally the modules are provided with lifting lugs. These enable them to be lifted onto ships to be taken to other locations. The Hab module mass of 22 tonnes is within the capacities of most shipping container cranes and lifting systems.

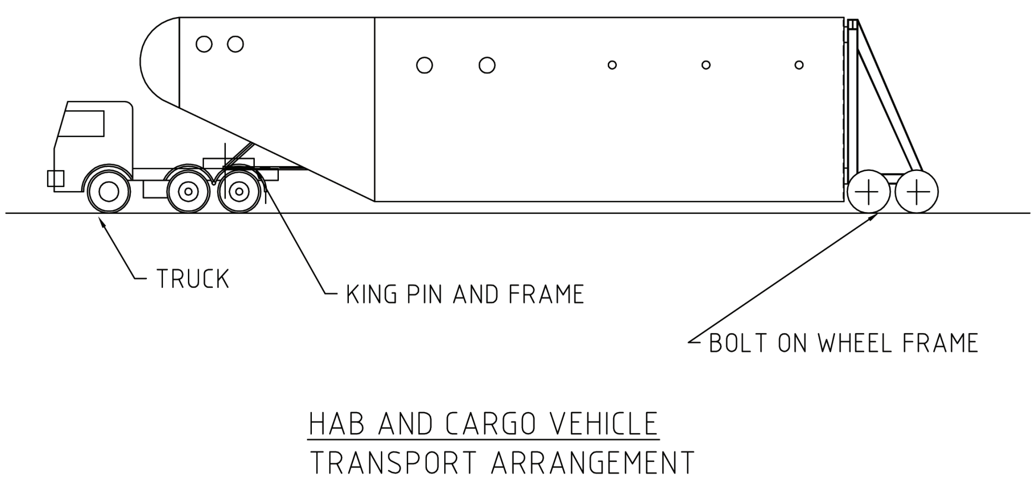

Figure 12. Transportation mode of MARS-OZ modules, using detachable wheels and a prime mover. Two such prime movers will be required to set up the base on the chosen site.

Opening, Promotion and Public Outreach

We suggest the opening of the base be part of the overall promotion of the project and the start of a public outreach program discussed in this section.

We propose to film the simulation of the assembly of the MARS-OZ base as part of the opening of the project. The plan is to locate the cargo vehicle at some distance from the Hab similar to an actual Mars landing. The Cargo Vehicle would have the Garage connected to its nose section. The rover, adaptor module and flexible extension airlock would be inside.

The promotion film might begin with the Mars explorers leaving the Hab in a small car and travel to the Cargo Vehicle. An actual electric car would be preferred but an open jeep or dune buggy could simulate un-pressurized rover.

The 'Mars' explorers would arrive at the Cargo Vehicle, unload the Starchaser Marsupial pressurized rover from the Garage section and detach the Garage from the nose section.

The pressurized rover would be hitched to the Garage in order to tow it to the Hab. Once there the adaptor and flexible extension module would be unloaded from the Garage. The explorers would then connect the modules and Garage to form the completed Mars-Oz base. The assembly process would be timed, and teething problems exposed for future reference thereby assessing the feasibility of such an assembly on the Martian surface.

Finally, after the base is constructed we suggest it is open to the general public, in a controlled manner as part of a public outreach program that encourages and inspires science and space exploration.

We suggest the construction of an Interpretation Centre at the Arkaroola village in order to manage visitor access to the site. This can be done at a low cost as existing buildings can be used for this purpose. The Centre can provide school students and other groups access to the base for workshops covering the theme, "Exploring the issues of living and working on another planet". It would consist of a 'mission control centre' with the PC communications and data link to the base. This would assist the educators instructing groups on planetary geology, astrobiology, psychology and other science issues. It is not intended the base is to open for uncontrolled tourism.

We can now briefly review the costs of the MARS-OZ project.

MARS-OZ COSTING

The total cost of the project at the beginning of 2005 was estimated to be AUS$1,400,000.

To date much the steel fabrication design has already been completed by the Mars Society Australia and issued for tender. This has greatly assisted in the estimation of the overall costs.

The table of the cost breakdown is shown in Table 1. In brief these costs are detailed as:

- The design review is to ensure the project is to the standard and compatible with the needs of the research institutions that intend to use it;
- The project approvals cover environmental management plans and field surveys to ensure the local authorities and aboriginal heritage requirements are satisfied;
- The design costs are to complete the base design to construction stage;

- The fabrication and transport costs to site costs cover the purchasing of equipment construction and prime mover transport to site. The costs do not include the provision of solar cells;
- The opening and promotion costs cover individuals involved in making the base assembly film. It is assumed the filming will be do free by a film company; and
- The contingency costs cover budget overruns and unforeseen events in the project.

The Interpretation Centre costs are not covered in this project.

Project Cost Components	**Costs (AUS $)**	**Percent of Total**
Design review	$40,000	3%
Project approvals incl. environmental	$90,000	6%
Design and Project management	$315,000	23%
Fabrication and transport to site	$790,000	56%
Opening and promotion	$30,000	2%
Contingency	$135,000	10%
TOTAL	**$1,400,000**	

Table 1. MARS-OZ simulated base cost breakdowns

We suggest nine months need to be allowed for the project from the award of funding to completion. This includes an initial 1-month concept review, a 3 month design period, 4 months to construct and fit out and 1 month for the promotion film.

CONCLUSIONS

We believe that the proposed MARS-OZ simulated base will provide a world-class platform for a range of Mars analogue studies for an international research clientele and promote interest and support for planetary science and exploration. The unique features of the MARS-OZ design and the Arkaroola region will complement existing and proposed analogue research sites in Utah, on Devon Island, and Iceland. MSA is seeking partners to enable to construct of the facility in the immediate future.

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