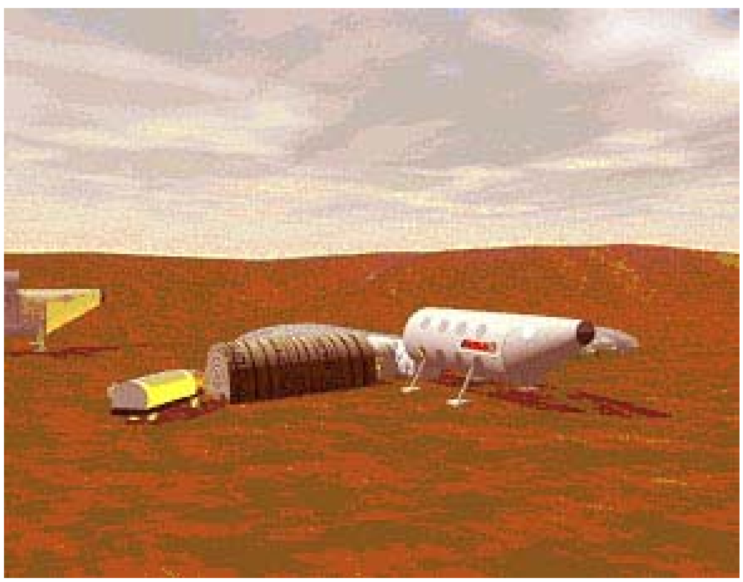
AN AUSTRALIAN MARS ANALOGUE RESEARCH STATION (MARS-OZ)

Addendum to Initial Proposal Document



Compiled by

Dr Jonathan Clarke

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1 INTRODUCTION

1.1 DOCUMENT SUMMARY

This addendum to the MARS-OZ proposal describes the recast interior configuration of the two modules, changes to the ancillary structures, and staging of planning and construction. The original proposal should be consulted for the background and details of overall project costing derived from other Mars Analogue Research Stations, which remain unchanged. The addendum includes three appendices, providing detailed wish lists for design features, compartment fit outs, and field science equipment.

2 MARS-OZ OVERALL CONFIGURATION

2.1 GENERAL ISSUES

The dimensions of MARS-OZ modules are set by legislated limits for loads on Australian roads. A length of 19 m is the maximum for unescorted loads and a width of 4.5 m is the maximum possible without self-escorted loads without police. The maximum weight for an unescorted load is 22 tonnes. Height is another critical parameter, 3.1 m will pass under all bridges, but higher loads will need some careful route selection to avoid low overhead bridges and other impediments. As a rule of thumb, biconics are typically three or four times longer than wide, setting the length of MARS-OZ at 18 m. A MARS-OZ 4.5 m in diameter and 18 m long, weighing no more than 22 tonnes therefore should be transportable anywhere in Australia as a single unit with self-escort and some route selection. The internal volume of a MARS-OZ module with these dimensions volume is 238 m^3.

For ease of manufacture and transport, a cylinder-cone is preferable to a strict biconic. The proposed MARS-OZ modules consist of a cylinder 12 m long and 4.5 m in diameter with a 6-m long upswept nose cone. The modules stand on four adjustable legs (fitted with skids to allow limited repositioning) 1 m above the ground but will need additional tie down as a precaution against strong winds. The main entry and egress will be through an airlock on the flat rear bulkhead of the habitat. I propose that the habitat be transported on a boat trailer and then jacked up off it, allowing the trailer to be removed from underneath.

To minimise logistic costs and local environmental impact, MARS-OZ should use local energy sources (preferably solar, see below), incinerate biological waste (as in FMARS and MDRS), and recycle water as much as possible. The materials from which MARS-OZ is constructed is not particularly relevant, weight, structural strength, durability, fireproofing, thermal insulation, sound proofing qualities are some of the factors which will need to be considered by the architect. Use of volunteer labour wherever possible during its fabrication should be sought to minimise costs.

The proposed MARS-OZ consists of five components: habitat module, cargo module, solar farm, support facility and inflatables. Each of these will be described in the following sections. Further details and requirements can be found in the Appendices.

2.2 HABITAT

The habitat module (Figures 1, 2) consists of two decks, each with 2.1 m headroom. Useable (as opposed to actual) floor space is ~122 m^2, about that of a small three bedroom house. This is greater than the North American 2-deck MARS (~100 m^2) but less than that of the three deck E-MARS (~150 m^2). The lower deck provides living and working space while the upper deck provides personal sleeping, washing, and toilet space with the cockpit in the nose providing additional workspace. The interior walls should be robust enough to provide soundproofing and privacy but, where possible, should not be load bearing, so that they can be moved if modifications are required. If possible the basic hull structure should be load bearing, to minimise the space take up by internal frames.

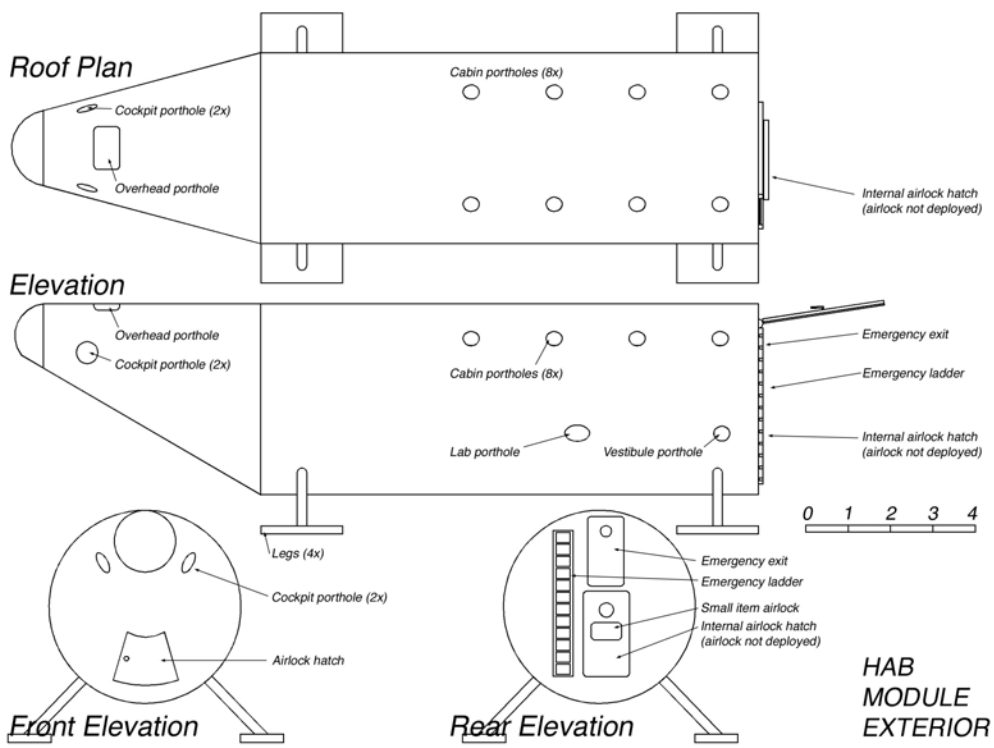

Figure 1 Exterior views of MARS-OZ habitat module

2.2.1 Upper deck

The cockpit, communication, and control deck occupies the forward most compartment of the upper deck where in extends into the nose cone. All communications and control systems for MARS-OZ should be centralised in this area. Eight aircraft type seats have fitted in the area with folding tables, providing the main area for computer work. There are storage and equipment racks in the cockpit compartment and a closing hatch and ladder leading down to the lower deck at the right rear size of the compartment.

The remainder of the upper deck consists of 6 2 X 1.75 m compartments arranged along the sides an accessed by a central corridor. At the forward end, two of these consist of combine toilet and shower compartments, the toilets should be of the incinerating type. A third compartment is a laundry and a fourth is a storage area. The remaining 8 compartments are sleeping cabins, formally fitted out for single occupants. If folding bunks are used it may be possible to accommodate couples in these.

A floor hatch and folding ladder towards the rear of the passageway allows emergency access to the lower deck. A hatch in the rear bulkhead provides and an emergency exit.

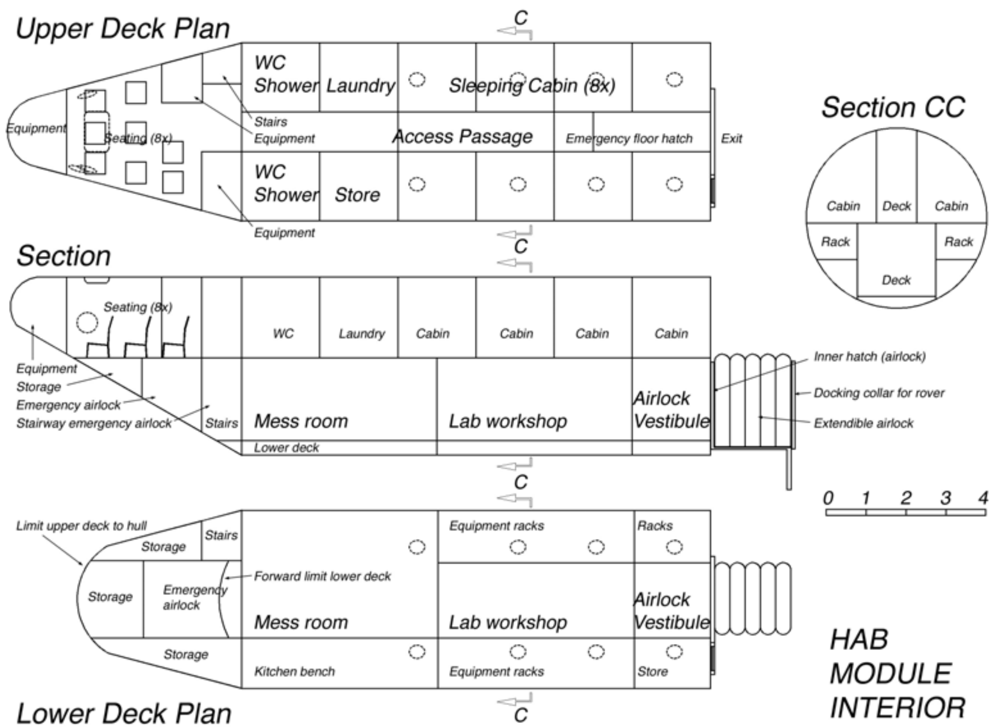

Figure 2 Interior views of MARS-OZ habitat module.

2.2.2 Lower deck

The lower deck is divided into four compartments by transverse bulkheads. The forward compartment is in the upswept nose cone. This contains the stair access to the upper deck, storage and equipment racks, and an emergency airlock hatch. The second compartment is 5 m long and contains a combined galley, mess and wardroom. All food preparation, dining, and recreation should be carried out in this area, there should be a folding table to seat eight, and folding exercise equipment on the walls. The third compartment is also 5 m long and comprises the workshop and laboratory space. Scientific equipment racks and workbenches are arranged along the sides and there should be a collapsing table for medical examinations. The aft 2 m long compartment provides an area for space suit stowage and dirty work, minimising dust spreading to the interior of the habitat. Side benches are available for work and sample preparation and storage. A hatch in the centre of the rear bulkhead leads to 4.5 m long folding ramp providing access to the surface. An inflatable or accordion-style airlock that can be docked with the Rover covers the ramp. There should also be a small airlock in the main hatch to allow transfer of equipment and samples without using of the main hatch.

Each living compartment should be provided with at least one viewing port. This will minimise the sense of enclosure in the habitat. The ports should be tinted to simulate Martian light conditions. Although not functionally necessary, thought should be given to external detailing to make it resemble an actual lander, e.g. thruster ports, thermal shielding, antennae, and winglets.

2.3 CARGO MODULE

The cargo module fills several roles. It provides a container for transport of various equipment items up to the size of the Rover to the field area and secure storage of them when the complex is not in use. It provides a dirty workshop and interim garage for the rover and houses a mock-up ascent stage (with the garage providing and airlock for access). The cargo module also contains tanks for consumable liquids, including water and fuel, stores of waste liquids from the workshop. Like the habitat module, consideration should be given to fitting external detailing to make it resemble an actual lander.

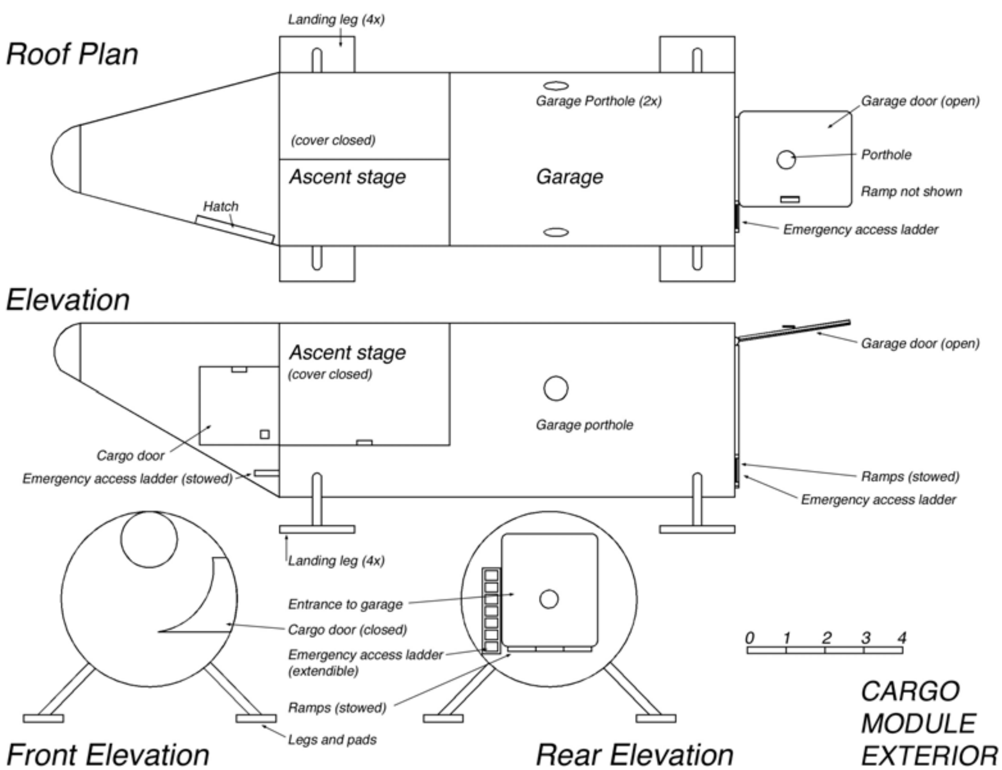

Figure 3 Exterior views MARS-OZ cargo module.

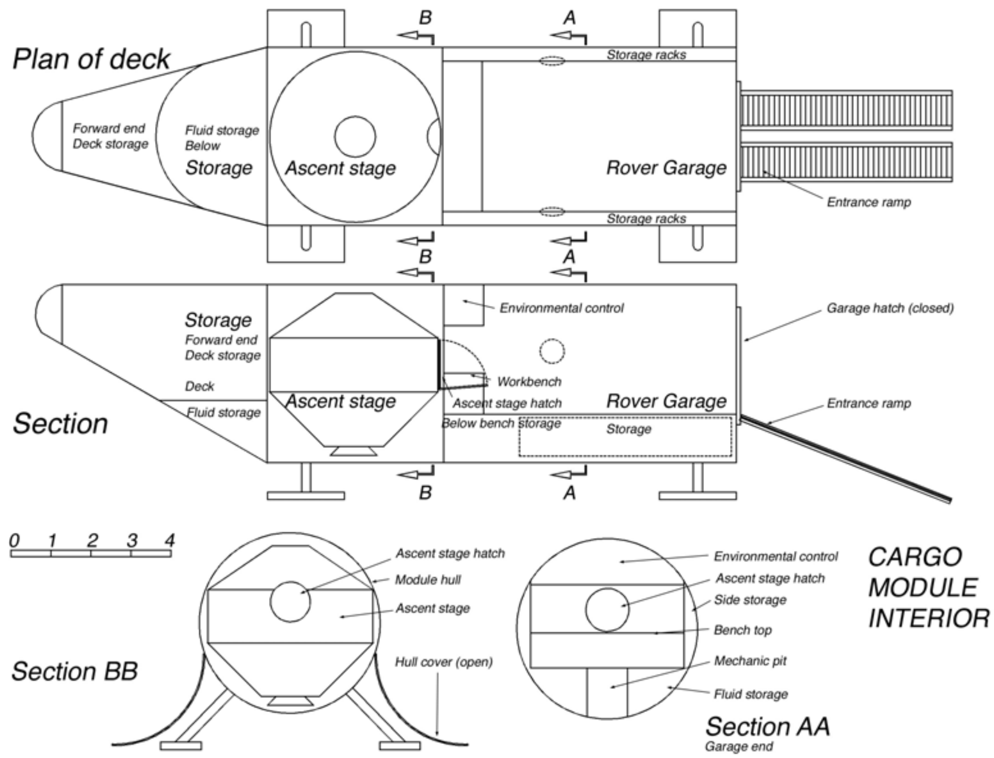

Figure 4 MARS-OZ cargo module interior views.

The cargo module contains 26 m^2 of “pressurised” work area. Added to the equivalent area in the hab module makes the total pressurised work area approximately equivalent to that of E-MARS. In addition there is ~10 m^2 of unpressurised deck space.

The forward nose cone compartment of the cargo module is 6 m long and has a deck 1.5 m about the bottom, resulting in 3 m of headroom. The below deck space is intended for bulk liquid storage and the remaining space for dry cargo. One or two gull-wing hatches on the sides of the compartment above provide access to the cargo. Folding landers allow access to the doors from the ground. The compartment should be fitted with an overhead travelling block and tackle to allow transfer of heavy items. The next compartment is 4.5 m long and contains a simple ascent stage mock up. The upper half of the hull consists of clam-shell doors that can be opened, allowing the ascent stage to be displayed. The bottom of this compartment will need to be fitted with a drain in the event of rainwater leakage. The rear compartment is the largest. It is 6 m long and has a deck 1.25 m about the bottom of the hull. As with the forward compartment, the space beneath the decks provides storage for liquids. In this area it is divided into two, with a 1 m deep pit to allow access to the under side of the Rover. There is a workbench and storage space along the forward bulkhead with a hatch set in it that allows access to the ascent stage mock up. The rear of the module consists of a flat bulkhead with a 2.5 m wide X 3 m high upward opening hatch. In the centre of this large hatch is a smaller one similar to those in the habitat module, in the vent the module will be used with normal sized inflatable access tunnels. Ramps 6 m long can be extended to the ground from stowage slots in the module to allow the Rover to be driven on and off. Liquid tanks in those forward end of the

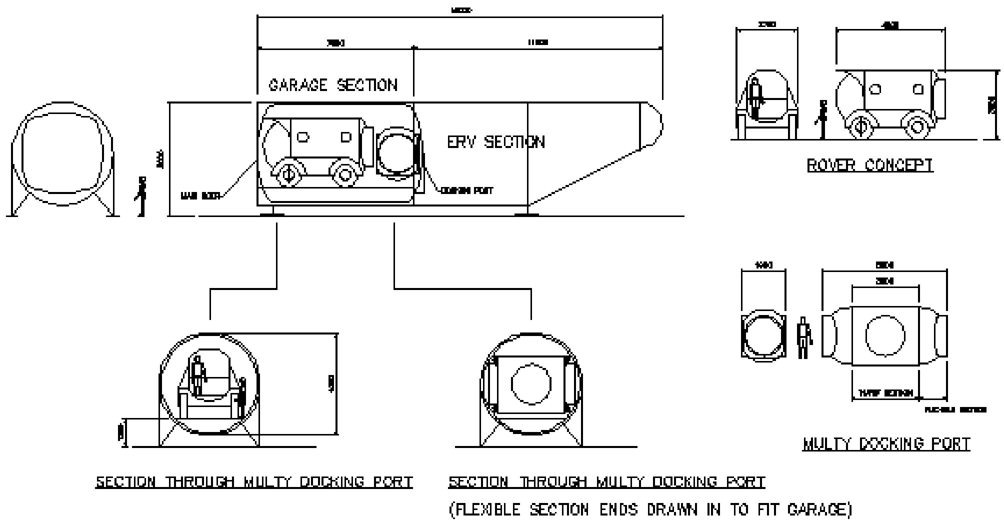

Figure 5 Alternative cargo module layout with detachable garage section.

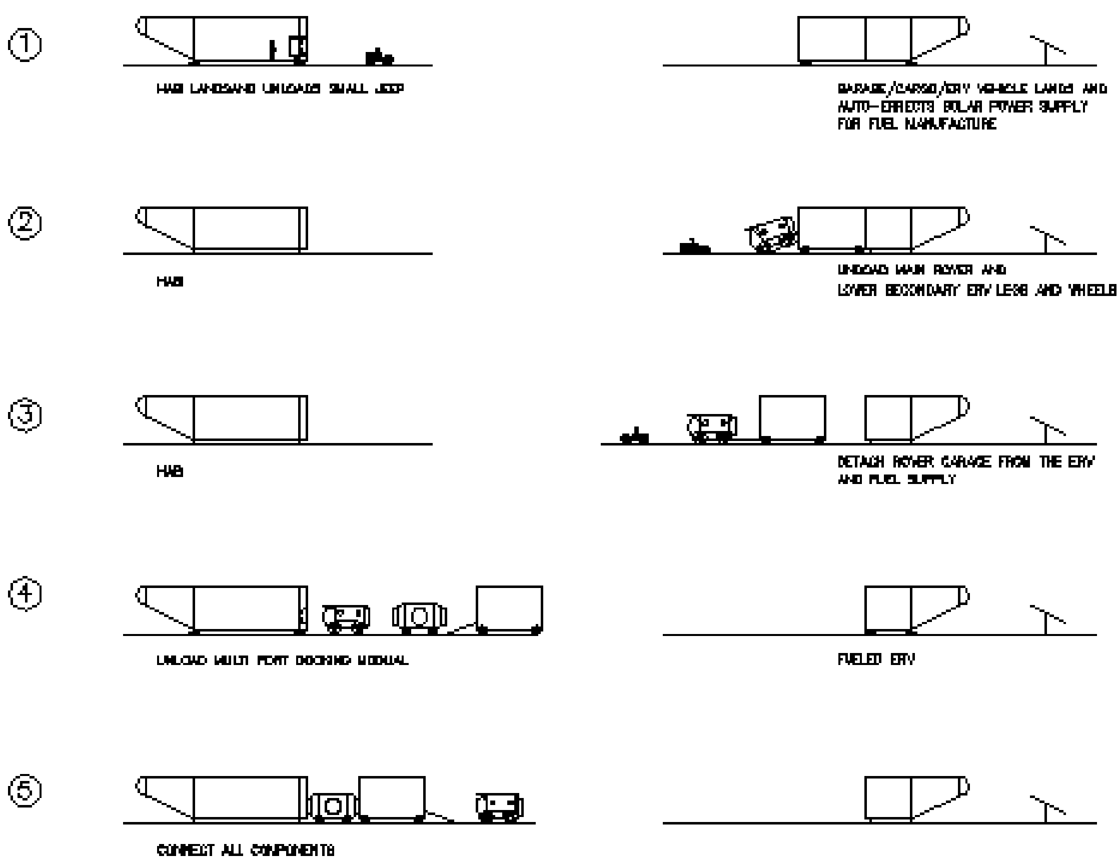

Figure 6 Cargo module layout with detachable garage showing assembly of infrastructure

lander provide ballast during loading and unloading of the Rover. The workshop and garage compartment is fitted with plumbing, power, and environmental control. The other compartments contain lighting only.

An alternative concept for the MARS-OZ cargo module is one where the garage and workshop section is detachable. This concept of David Willson is illustrated in Figures 4 and 5. The justification for this is that it allows the garage to be more easily moved close to the habitat module, at the expensive of greater complexity. These alternatives need to be carefully weighed during the formal design.

2.4 POWER SUPPLY

Previous MARS at Devon Island and Utah have relied on diesel power units. It would be desirable from many viewpoints if the power needs of MARS-OZ could be supplied entirely from local resources, as they would on Mars. These reasons include minimising logistic costs and environmental impact, imposing energy use discipline in habitat design, and providing a showcase for self sustained architecture. Solar energy is the most relevant for Mars analogue purposes, but wind generators could supplement this.

2.5 INFLATABLES

Inflatable structures or their analogues can play a key role in MARS-OZ. Three roles are immediately evident. Firstly they can provide greenhouses for biological recycling of water and food production; secondly they can provide the equivalent of a pressurised garage for the Rover vehicle; thirdly, they could provide transfer tunnels. Inflatable structures or their analogues could be added incrementally, however the transfer tunnels and garage would have the highest priority. Adequate tie down and anchorage of the inflatables against high winds will be necessary.

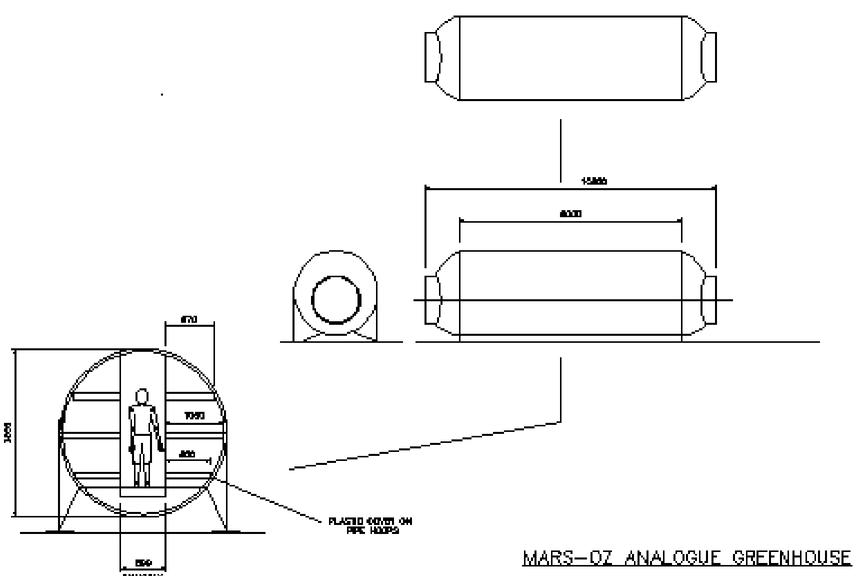

Figure 7 Inflatable greenhouse concept

The tunnels should be of two sizes, normal (2.5 m high and 2 or 2.5 m across would provide personnel access. Segments of these tunnels to the side could function as airlocks. Larger tunnels, 3 X 3 m would allow the Rover to be driven down the ramp and into an inflatable garage or inflatable vehicle airlock under pressurised conditions.

A garage large enough to contain the Rover vehicle plus extra working and storage space is also desirable. It would allow servicing of the vehicle under cover equivalent to a pressurised environment on Mars, and space to sort and store samples and work on other equipment. Such an inflatable could be 9 X 6 X 3 m. However, ventilation of fumes in an inflatable structure could be difficult, which is why the garage within the cargo module may be more desirable. Greenhouses could grow from an initial experimental structure to progressively large structures capable of growing food and recycling water. For greenhouses it would be desirable to have the transparent material transmit as much light as would be experienced on the surface of Mars, and of the same spectral characteristics. A greenhouse module based on the MARS-OZ cargo module may, however, prove more practical than setting one up in an inflatable, especially given the problems of having transparent materials of sufficient strength on Mars.

David Willson has made some draft designs of similar inflatable concepts with slightly different external dimensions. A greenhouse version is shown in Figure 5, while the docking adapters are shown in Figure 8. The multi docking adaptors in this concept have a 'hard' midsection and a flexible fabric end sections. This enables the port to fit in the garage and allows it to be a 'flexible coupling' when coupled to the Hab and Garage.

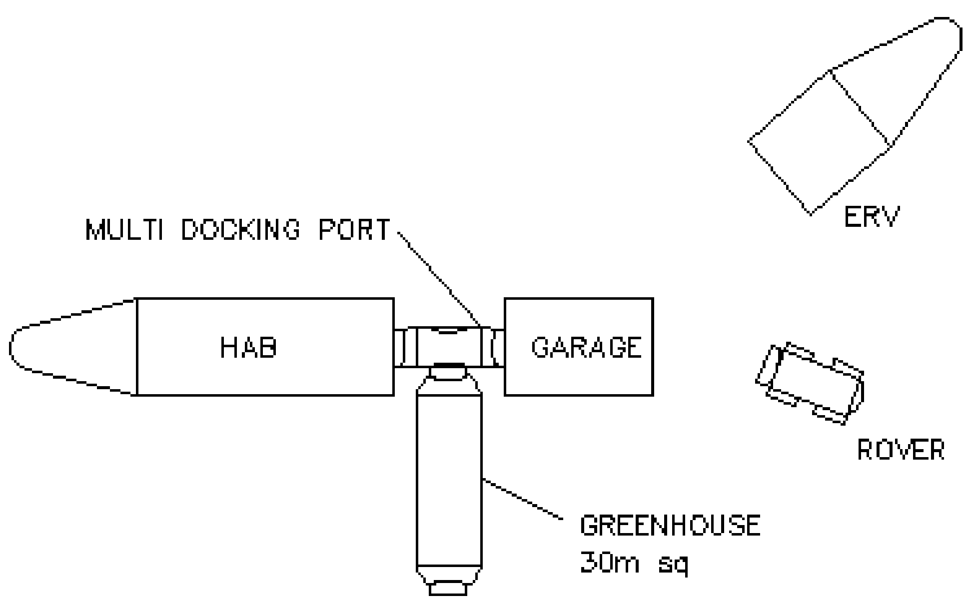

Figure 8 Plan of the MARS-OZ facility.

2.6 SUPPORT FACILITY

Although the MARS-OZ crew will be living entirely within the habitat complex there will be a need for a support facility and associated accommodation to monitor and assess the work program, control visitors, and provide outreach. Ideally those would be located at Arkaroola to minimise additional construction and to maximise public outreach and co-operation with the Arkaroola village.

3 MARS-OZ PROGRAM STAGES

I have revised the stages for the assembly of MARS-OZ into the following stages.

- **Stage I** regional selection and preliminary design
- **Stage II** detailed design. Scoping of legal and legislative responsibilities, and site selection.
- **Stage III** Modules structurally complete. External and internal structure assembled, but with only temporary lighting, capable of public display.
- **Stage IV** Modules functionally complete. Power, lighting, plumbing, and environmental systems operational and all fittings in place. Basic communications and workshop installed but no science facilities. Capable of system integration tests.
- **Stage V** Modules deployed to Arkaroola. All science equipment installed (items can be added to progressively).

The projected division of the total project cost of $700K (worst case scenario) using the items from the original proposal is shown in the following table and breakdowns from previous studies.

STAGE	**COST**
Stage I	$30K
Stage II	$70K
Stage III	$250K
Stage IV	$230K
Stage V	$120K
Total	$700K

Table 1 Projected cost breakdown for MarsOz construction.

4 MARS-OZ STAGE II

4.1 INTRODUCTION

The completion of the MARS-OZ proposal document marked the end of stage I of the project. This stage included the following:

- Site selection process during the Jartimarra-1 expedition.
- The decision to use a horizontally landed biconic design, rather than a "tuna can", as the basis of the habitat.
- A sketch design of the MARS-OZ complex, including the habitat, cargo module, and associated infrastructure including inflatables and solar farm.

MSA is now ready to proceed to Stage II of the project. Stage II will consist of the following:

- Detailed formal design by a qualified architectural team, including costing.
- Identify the construction firm and determine who will supervise assembly.
- Development of an operational plan, including operating costs
- Specific site selection, including approval from landowners, in the Jarntimarra-2 expedition

Following are some more detailed requirements for each of these components.

4.2 FORMAL DESIGN

I propose that the MARS-OZ proposal and a series of technical specifications under development be given to an architectural firm to draw up a detailed design. I suggest that firms with experience in designing boats or environmentally sustainable housing are the most suitable. The formal design will allow determination of construction costs, consumable needs, environmental impact, and mobilisation and logistic costs.

- Experience in designing efficient use of limited volumes within tight weight and dimension specifications.
- Experience in the appropriate construction materials and methods.
- Experience in efficient consumable use, including power and water.
- Experience in transporting large loads over long distances by road.
- There are numerous firms in Australia capable of competitive tendering for the construction of MARS-OZ.

The formal design will allow determination of construction costs, consumable needs, environmental impact, and mobilisation and logistic costs.

4.3 OPERATIONAL PLAN

The operational plan will require the following:

- Transport and establishment of the facility near Arkaroola.
- Definition of environmental impacts and legislative requirements.
- Public liability and indemnity plan.
- Provisional plan for annual operating cycle.
- Rental due to land owner.

These will allow for a provisional operating budget and guide negotiations with landholders in the Arkaroola region.

4.4 JARNTIMARRA-2 EXPEDITION

The aims of the Jarntimarra-2 expedition should of the following:

- Visit all properties and property owners in the Arkaroola region to present them with the MARS-OZ proposal and operating plan and negotiate with them for a suitable site.
- Select a specific site suitable for the establishment of MARS-OZ, using a ranking procedure similar to that used in Jarntimarra-1.

I recommend that the expedition consist of no more than four people, the president, Guy Murphy, the PR officer, Jennifer Laing, the person coordinating project Marsupial, Graham Mann, and myself, as coordinator of the MARS-OZ project. A larger team may be seen as an imposition by local landholders. I suggest the expedition will need 2 weeks for detailed inspections and negotiations. Transport and accommodation should be provided by 1 4-berth 4WD campervan or 2 2-berth 4WD campervans. This will provide expedition members valuable preliminary experience.

4.5 BUDGET

Design (including contract, telephone expenses, and some travel and accommodation):	$45,000
Operation planning (including possible legal and environmental consultant costs):	$20,000
Jartimarra-2 (including travel to Adelaide, 4WD hire, and food):	$5,000
Total	**$70,000**

Table 2 Projected budget breakdown for Stage II.

Potential sponsors need to be approached immediately to allow Stage II to proceed.

4.6 ACKNOWLEDGEMENTS

This addendum is based on the comments made by many on the original proposal. They included Dr Roberto Antiori, Dave Cooper, Paul Grey, Dr Robert Hart, Jason Hoogland, Marshall Hughes, Jennifer Laing, Dr Graham Mann, Guy Murphy, and Michael West. Figures 1-4 were prepared from my originals by Tristan d'Estree Sterk and Figures 5- 7 by David Willson, both of whom also made helpful suggestions.

APPENDIX A

MARS OZ TECHNICAL SPECIFICATIONS

Dr Jonathan Clarke

A1 MARS-OZ HABITAT

A1.1 VISION

Modules that can be trucked on site as a self-escorted unit and, in conjunction with the associated cargo module, provide minimal impact living and research space. The habitat should recycle 80% of the water used and incinerate faecal matter (and possibly other solid waste) with a minimum of odour. Electrical power should be provided by solar energy. The systems should be repairable with a minimum of specialist input. On completion of stay the unit should be capable of being trucked to another site leaving only minor rehabilitation of the previous site.

A1.2 CONFIGURATION

The configuration should be based on that of the MARS-OZ proposal. The core concept of MARS-OZ is a horizontally landed structure of a size that can be transported on site as a unit. Currently the configuration is a cylinder with an upswept nose cone. Changing this configuration to make more efficient use of the available volume or to reduce cost, for example to a slab-sided structure or one with a more conventional down swept nose, would be acceptable.

A1.3 DIMENSIONS

The dimensions of the MARS-OZ modules are currently set at 18 m long and 4.5 m in diameter, to comply with Australian load transport laws. The modules should be set escorting on the road, to minimise costs. However headroom in the two-deck habitat module and clearance in the garage for the Starchaser Marsupial Rover is already tight. Depending on the thickness of the hull and decks of the modules, it may be necessary to increase these dimensions slightly.

A1.4 MANAGEMENT STRUCTURE

Once funding is achieved we will establish a management structure that consists of a project manager (presently Jonathan Clarke), a business manager who will oversee the project. There will be leaders for each of the systems listed below. These will work with a design team, under the supervision of the managers, to complete the design.

A1.5 SYSTEMS

A1.5.1 Construction – *David Willson*

- Can be wood, aluminium, fibreglass, or a combination, must be of a fire resistant nature
- Must be less than 20 tonnes in weight
- All materials should be hypoallergenic and low toxicity
- Must be capable of easy maintenance and modification.
- Internal surfaces must be capable of easy cleaning (i.e. minimal sharp internal corners)

- Laboratory and work areas must be capable of rapid modification and addition of equipment

A1.5.2 Power and energy – *Paul Grey*

- Preferably renewable, with solar as first preference and wind as second. Fuel cells are another possibility.
- Must be capable of being carried in cargo module along with other external equipment (rover, water, fuel)
- Must be capable of meeting maximum load over extended periods with adequate reserve
- Must be capable of upgrading to meet demand (such as analytical equipment, or have significant reserve capacity
- Can be either 240 or 12 volt
- Gas can be used for cooking, water heating and toilet, although electricity is 1st preference
- Emergency power supply either as a UPS or that can be started without breaking simulation

Note: MDRS found that 7KW was too low, and now has a 20 KW LPG system (110V)

However, "solar homes" can run on as low as 40W (12V), so perhaps 100-200W would be ample – but note the load of electrical equipment below.

A1.5.3 Environmental control – *Paul Grey*

- R/C air conditioning or equivalent, capable of maintaining all parts of the habitat at temperatures of 15-25 degrees.
- Automatic operation with manual override.
- Ventilation for sealed habitat environment within legislated specified limits
- If air conditioning system produces condensed water this should be of potable quality or easily collected and transferred to purification plant.

A1.5.4 Plumbing – No one yet assigned

- Water can be supplied from external source, such as tank in cargo module, which must be large enough to meet a 2 week sim with 8 people, using ~20-30l per day.
- Piped hot and cold water supply to bathroom/toilet/washing area, wardroom/mess, lab/workshop, and dirty work area.
- Sink in laundry/washroom/toilet, mess/wardroom, lab/workshop, and dirty work area
- Shower
- A water and energy efficient washing machine should be installed

- Grey water should be collected and recycled at 80% efficiency or better. Both biological and mechanical/chemical recycling are acceptable, as are hybrid systems. The recycling system should be within the Mars Oz complex. The recycling system should be able to handle chemical as well as biological contaminants
- Toilet should be of the incinerating type, either gas or electricity. The toilet should be able to produce an inert ash and cope with sustained daily use by up to 8 people. Two toilets should be installed, if possible.
- Consideration should be given separate urine collection for eventual recycling.

A1.5.5 Electrical – *Paul Grey*

- Each compartment would be provided with at least one power outlet, and more (4-6) for larger compartments
- Independent emergency power distribution
- Energy efficient interior lighting should be installed to provide sufficient light levels.
- Exterior lighting for all round floor lighting when needed and a navigation beacon should be available
- Emergency interior lighting
- Energy efficient dryer (use of waste heat from other systems would be desirable
- Energy efficient washing machine
- Hand basin
- Two incinerating toilets
- Centralised vacuum cleaning system
- TV/video, radio, sound system
- Drinks fridge (kitchen)
- Two microwave ovens or electric stove (if gas option not used)
- Boiling water source (or electric kettle)
- Small fridge + freezer (lab)
- Waste compactor
- Information systems (see below)

A1.5.6 Information systems – *Adrian Veasey*

- Server
- LAN
- A MARS-OZ computer that would function as the mission log and possibly monitor and control the internal environment. This could be accessed by workstations in the cockpit and lab areas.
- Up to 6 ports for laptops in the cockpit area built into the seats and a similar number in the lab

- Facilities to download and upload data from palm pilots to lab tops and habitat computer
- Long range communications (SAFMARS, satellite phone, or Telstra solar phone) for back to mission control, other MARS, www, etc.
- Medium range communications (single HF) with rover, Arkaroola, RFDS
- Short range communications (UHF), people on EVA
- Internal communications (2-way intercom) between compartments
- Fax and email facility, long-range link.
- Combined fax, printer and photocopier
- Major electronic items must be easily demountable for storage and repair.
- Antennae must be mounted on the roof of MARS-OZ

A1.6 COMPARTMENT FITOUTS

A1.6.1 Toilet/washroom/laundry

- Dryer
- Water efficient washing machine
- Hand basin
- Two toilets, each in own cubicle
- Water efficient shower, in own cubicle

A1.6.2 Wardroom/mess

- Entertainment equipment such as TV, radio, sound system, and VCR
- Stove and/or microwave bank (microwave bank preferred)
- Kitchen fridge (small, drinks only)
- Extraction fan or filter in kitchen area
- Waste compactor
- Storage space
- Kitchen benches and dining table
- Chairs for up to 8 people
- Collapsible exercise equipment against bulkheads

A1.6.3 Laboratory

- Workbench 1 X 3 m
- Sink and water supply (possibly under movable cover on bench)
- Work station and LAN ports for 4 lap tops
- Collapsible medical examination table

- Equipment and storage racks along 6 m of wall, including chemical store
- Numerous power outlets
- Fridge and freezer
- Incubator
- Autoclave
- Bio safety cabinet and hood
- Hot plate
- Sterilizer
- Chairs for 4 people

A1.6.4 Vestibule

- Power tools work area for electrical, small mechanical, and electronic equipment
- Sample and equipment cleaning area
- Workbench
- Storage space and equipment racks
- Spacesuit storage
- Space suit cleaning area

A1.6.5 Sleeping cabins

- Should be rapidly reconfigurable from single to double
- Each should have appropriate stowage
- Each should have main light and reading light
- LAN port optional
- Power supply

A1.6.6 Control, command and communications compartment

- Control of all habitat systems centralised in cockpit
- Communications also centralised in same area
- Cockpit area should be designed for visual verisimilitude to a spacecraft cockpit
- Seating for up to 8 people in aircraft seats. All seats should be demountable and fitted with folding tables and LAN ports. The seats are envisaged to resemble business class seating in commercial aircraft.

A1.6.7 Emergency equipment

- There should be at least two emergency exits in addition to the main exit. The toilet and washing compartment can double as an emergency airlock, with an exit hatch forward or in the side. A third exit hatch should be available at the rear of the lower deck

- An emergency deck hatch and ladder should allow access between decks at the rear end of the habitat interior.
- Fire/smoke detectors in each compartment
- Extinguishers in each compartment
- Supply of smoke masks and goggles for up to 8 people

Note that a sprinkler system may be either practical or desirable

A1.6.7 Miscellaneous

- The habitat must be able to store food for a minimum of one month.
- The habitat must functional with a minimal of work: driven to sit, jacked up onto legs, airlock and ramp deployed, power and water plugged in.

A2 CARGO MODULE

A2.1 VISION

The cargo module simulates a cargo lander that arrives on Mars ahead of time that contains assorted stores, the rovers, and the ascent stage. For Mars Oz the cargo module carries equipment on site, stores water for the hab, fuel for the rover, and has a garage for the rover that doubles as a heavy workshop. The cargo module has a 4.5 m long centre section blanked off to simulate the space taken by the ascent stage. It would be desirable to have a simulated ascent stage within the space, accessed by a tunnel from the garage. The upper part of the ascent stage compartment should consist of clamshell doors.

A2.2 CONSTRUCTION

- Must be of the same construction and materials as the habitat
- Must be deployable in the same manner as the habitat
- Be equipped with large access hatches

A2.3 CAPABILITIES

- The cargo module must be capable of storing at least 1 month's water for the habitat at maximum usage.
- The cargo module must be capable of storing at least 1 month's fuel for the rover
- The cargo module must be capable of storing, maintaining, and deploying the rover
- The cargo module must contain a range of storage racks for other consumables that cannot be stored in the hab sufficient for at least 1 month of simulation
- It must also provide secure storage of equipment during the off-season.

A2.4 SYSTEMS

- The access hatches must be lockable
- The cargo module must be equipped with basic internal and external lighting
- The interior must have strength and anchor points for cargo in transit
- The storage areas should be fitted with travelling block and tackle to allow safe loading and unloading of heavy items
- There must be an under floor tank for storage of contaminated wastewater from the garage/workshop with sufficient capacity for the length of the simulation.
- Communications link with both habitat and people on EVA/rover.
- There must be appropriate fire sensing and extinguishing equipment.

A2.5 GARAGE

- The rover must be capable of being driven into and out of the garage
- The garage must be fitted with tools, storage, and workspaces for extensive repair and maintenance on the rover, and work on large wood, metal, and plastic items from the habitat.
- The garage must be fitted with appropriate power, lighting, and air conditioning
- There should be a tap and sink for washing of parts. The washing water is likely to be contaminated and should be stored in a tank until the end of the simulation.
- Fire extinguisher and smoke alarm

APPENDIX B

INTERIOR EQUIPMENT FITOUT

Dr Jonathan Clarke

B.1 DETAILED LAB/WORKSHOP EQUIPMENT FITOUT

B1.1 GEOLOGICAL LABORATORY EQUIPMENT – *DR JONATHAN CLARKE*

- Binocular microscope with digital camera
- Petri dishes
- Lab bench and mounts for equipment
- 2.5 m of work bench (to be shared with biology)
- Munsel chart
- Small spatulas
- Sink
- Distilled water
- Buffer solutions for pH
- Sample bags
- Labels
- Markers
- UV lamp
- Gamma ray spectrometer
- Geiger counter/scintillometer
- PIMA
- Pen scratcher/magnet X 2
- Hand lens X 2
- 10% HCL
- Peroxide
- Geology hammer
- Hand held pH meter
- Hand held salinity meter

B1.2 BIOLOGICAL LABORATORY EQUIPMENT - *ROBERTO ANTIORI*

- 2.5 m of bench space and rack space along walls.
- Centrifuge (20x20x20cm; LxWxH)) - 230V, 50/60 Hz, 0.25kW. It has a 1A fuse.
- Electrophoresis tank (25x12x12cm) and power pack for electrophoresis (15x10x6cm) - 100 to 240V, 50-60Hz, Maximum power 60W.
- Camera for photographing DNA samples (35x20x25) - (share with geology)
- Handheld UV transilluminator (~ 10x10x25 cm) to be shared with geology

- PCR machine (55x35x35cm) - 240VAC, 50Hz, 5A MAX. This machine has three fuses at the back. These are labelled - F1: 6.25AMP, S.B. 250V; F2 - same as F1; F3 - 0.5 AMP, S.B. 250V.
- Vortex (17x12x17cm) 220V, 50 Hz, 0.5A
- Fridge (4 degrees) and freezer (at least –20 degrees).
- Incubator to maintain a constant temperature of 37 degrees Celsius
- Autoclave
- Bio safety cabinet and hood
- A small amount of bench space to place the equipment and do the experiment
- Glassware - 1.5L flask, at least 2 500mL beakers, 1L volumetric flask, 100 mL beakers, 100 mL graduated cylinder, petri dishes, 1.5 mL Eppendorf tubes, 15 mL Falcon Tubes, 50 mL Falcon Tubes
- Magnetic stirrer
- Hot plate
- Sterilizer (possibly UV)
- Water filter (to produce laboratory grade water)
- Chemicals - 100% Ethanol; sterile deionized water; Bleach; Luria Broth (LB); yeast extract; biology-grade NaCl; antibiotics (as necessary); other chemicals as needed by specific researcher, antiseptic solution (like lysol wet wipes)
- Chemical secure storage
- Epifluorescent microscope; positive control slides; lens paper; immersion oil; dust jacket; slides; coverslips
- Sundry equipment – loops, bunsen burner/ethanol lamp, burner fuel, lighter; toothpicks, gloves, pipette, pipette tips; biohazard bags, spatula; weighing paper; forceps/tweezers, ethanol-proof sharpies, lab tape, magnetic spin bars, safety goggles, scales.

B1.3 MEDICAL EQUIPMENT – *DR ROBERT HART*

Exercise equipment carried in mess compartment, appropriate power and cabling for monitoring equipment must be available in this compartment

- Folding exercise equipment (stored in ward room)
- 5 m of bench and rack space along wall
- Trauma table (folding)
- Ventilator and associated equipment and oxygen
- Defibrillator
- ECG
- EEG (shared with pyschologists)
- Thermal control equipment
- Pulse oximeter

- Non-invasive blood pressure monitor
- Blood gas analyser
- Urinalysis kit
- Intravenous access: standard supply of needles, giving set and a rate controlled pump
- Cross-matched blood or haemaccel and refrigeration support
- Emergency surgery kits, particularly: peritoneal lavage, thoracostomy, cricothyroidotomy
- Stabilisation for spine injuries
- A Doppler-capable ultrasound machine with multifrequency probes
- A digital x-ray machine, with minimum detector size 43X35 cm High bandwidth telemedicine capability
- Supply of ER drugs, medications dressings, splits etc., suitable for isolated and remote environment

B1.4 PSYCHOLOGICAL EQUIPMENT – *DR STEVEN DAWSON*

- PC based, later compact EEG equipment may be used

B1.5 WORKSHOP/AIRLOCK VESTIBULE - *PAUL GREY*

- Well-ventilated bench (with extraction/filtration fan) about 1m by 2m
- Storage cabinets for chemicals and tools
- Bench lamp
- Large illuminated magnifying glass
- Fine-tipped soldering iron
- Desoldering iron
- Medium size bench vise
- Small drill press
- Dremel tool
- Small swivel vice or soldering 'helping hands' vice
- Multimeter

B1.6 GARAGE WORKSHOP IN CARGO MODULE - *PAUL GREY*

- 1 x 2m metal top bench, with a largish vise for heavier metal fabrication and welding
- Pedestal grinder
- Pedestal drill press
- TIG or MIG welder

- Small/medium lathe
- Hand angle grinder, drill
- Cut-off drop saw
- Welding screens
- Jigsaw
- 1 x 2m wood top work bench, with wood-vise, for wood and plastic work
- Dust extraction/collection duct
- Saw
- Router
- Sander
- A range of wood and plastic handsaws, hammers, fasteners, glues, clamps, etc.
- A wet area/sink is needed in any garage for washing parts/cleaning, preferred option a well built into bench with a solid cover over for when not in use.

APPENDIX C

FIELD EQUIPMENT

Dr Jonathan Clarke

C1 FIELD EQUIPMENT

C1.1 GEOLOGY – *DR JONATHAN CLARKE*

C1.1.1 In vehicle

- Geology hammer X 2
- Large spatula or scraper
- Data logger X 2
- Digital camera
- Centimetric colour scale
- GPS with barometer
- Compass/clinometer
- Jacobs staff
- Sledge hammer
- Mattock
- Spade
- Linked GPS, laptop and maps
- Rock saw
- Hand drill
- Hydraulic soil corer

C1.1.2 From lab as required

- Hand held pH meter
- Hand held salinity meter
- Munsel chart
- Small spatulas
- Sink
- Distilled water
- Buffer solutions for pH
- Sample bags
- Labels
- Markers
- UV lamp
- Gamma ray spectrometer
- Geiger counter/scintillometer

- PIMA
- Pen scratcher/magnet X 2
- Hand lens X 2
- 10% HCL

C1.2 SOIL AND THERMAL POOL MICROBIOLOGY

- ROBERTO ANTIORI AND MICHAEL GILLINGS

- Sample scoop
- Sterile water/tissues - to clean tools between samples.
- Device for measuring pH (shared with geology
- Temperature probe
- 50 ml plastic centrifuge tubes (sterile) for collection of samples
- 5 ml plastic tubes (sterile) for collection of samples
- Surgical gloves
- Small fridge or freezer in vehicle
- Sample tube rack
- Digging tool – e.g. a garden spade/trowel (shared with geology)