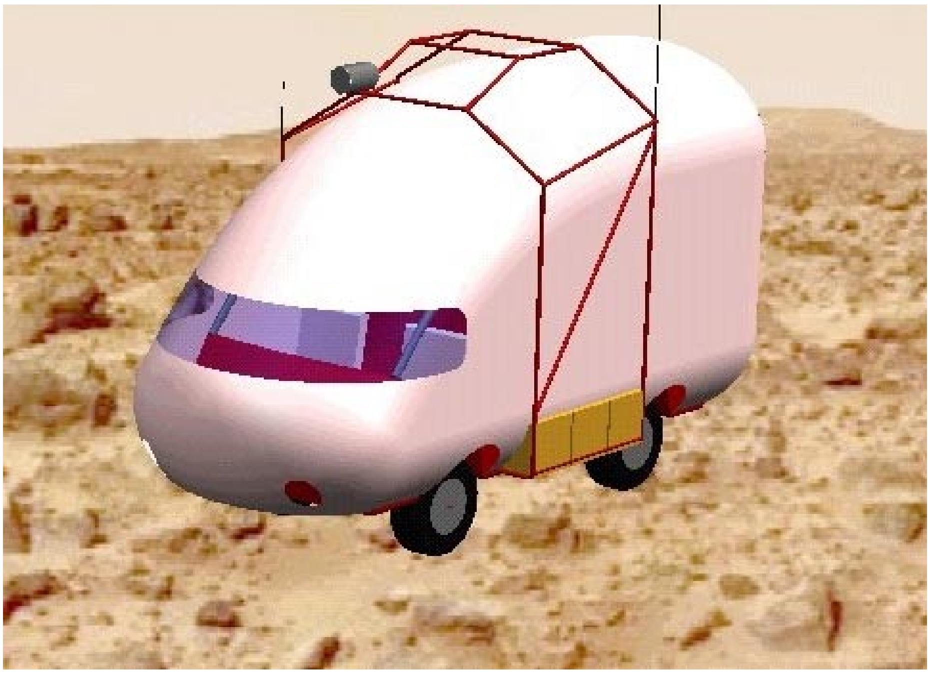
Project Marsupial

Human Operations Prototype



a proposal for

The Mars Society's
Mars Analog Rover Initiative

by

The Mars Society Australia

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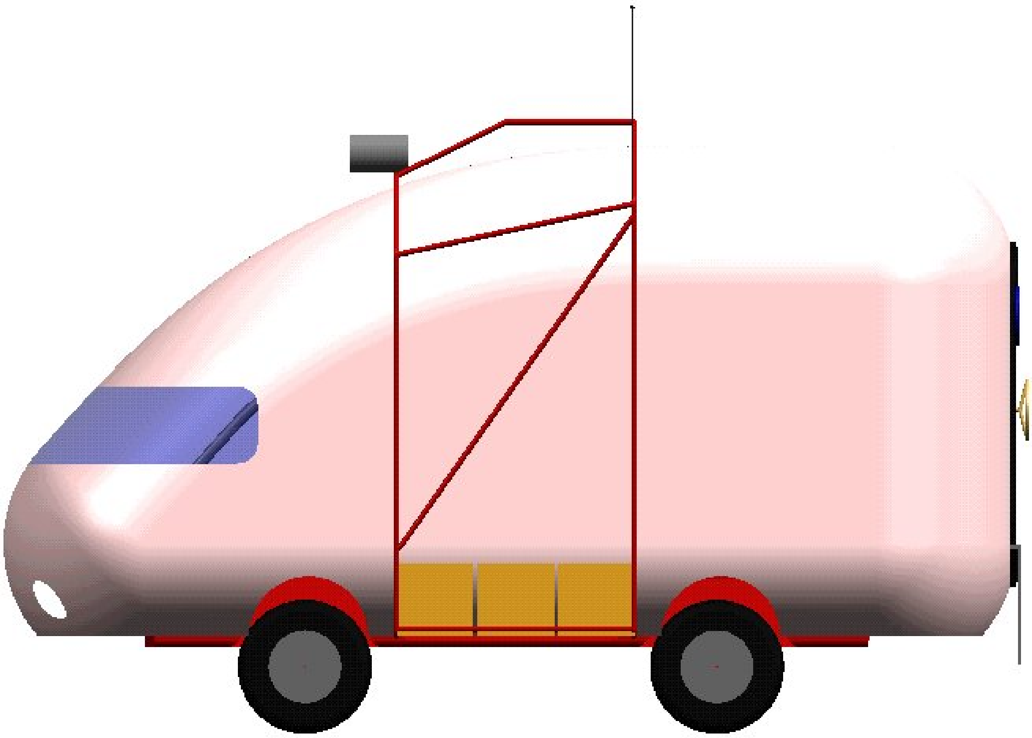

Figure 0.1. The Project Marsupial Human Operations Prototype

Project Marsupial:
From Australia's Red Centre to the Red Planet

1. Introduction

1.1 Using this Document

The first two sections of this document comprise an introduction to the Mars Society Analog Rover Initiative, Project Marsupial, and the Project's prototype vehicle, the HOP. The third section, *HOP Project Organisation*, addresses logistical issues, including a detailed schedule and budget. The fourth section (*HOP Design*) and associated appendices detail the HOP concept. The fifth and final section, *Project Team*, lists project team members and provides contact details for the HOP project and the Mars Society Australia's Technical Programme. A glossary is included in section 6 for those unfamiliar with special terms used throughout this document to describe the project and its objectives.

1.2 The Mars Analog Rover Initiative

The Mars Society Analog Rover Initiative commenced in February 2000 with release of a Specification and Request for Proposals. The objectives include:

- to develop an unpressurised, analog Mars manned rover vehicle acting as a testbed for developing strategies and operational protocols for human surface exploration, and complementing planned establishment of a global network of Mars Research Stations
- to provide an avenue and focus for Mars Society members to actively engage their skills, creativity and enthusiasm, helping maintain motivation and momentum across the organisation,
- to assist in promoting the Mars Society and attracting wider attention with credible scientific work,
- to ensure the vehicle *looks* and *feels* like a real Mars rover, maximising its effectiveness in meeting the objectives above.

It is not an attempt to develop an optimal vehicle for crewed Mars missions, but rather to select a good baseline platform with which to test crew procedures and other assumptions in analog environments.

The Mars Society Australia (MSA) submitted an initial proposal in August 2000 for a custom hybrid-electric vehicle, Wombat, as part of an Australian Mars analog rover programme called Project Marsupial. This extends the Mars Society Rover Initiative to include additional objectives:

- application of local expertise in electric vehicle technology and composites to demonstrate the opportunity for Australia to make a contribution to future planetary mission surface hardware,

- contribution to the design database for Mars pressurised rovers by building and operating a vehicle based on particular engineering concepts with an emphasis on mobility.

In order to satisfy Mars Society Rover Initiative objectives, including the need for a fast development cycle of 12 to 18 months, it is necessary to stage Marsupial with the Human Operations Prototype.

For further information:
Project Marsupial: http://www.marssociety.org.au
The Rover Initiative: http://www.marssociety.org/projects/rover/index.asp

2. Definition of Objectives

The HOP has the following objectives (in order of priority):

(a) to provide a pressurised rover operations research platform, achievable in the near-term;
(b) to raise the profile of the Mars Society in Australia and internationally;
(c) to make a credible scientific contribution to Mars human operations research,
(d) to assist in the design, marketing and fundraising for a high mobility, Wombat-like electric analog rover,
(e) to raise the profile of space research in Australia, particularly by undertaking the first Australian planetary surface operations simulations

2.1 Scope

The HOP will provide a basic operations research platform without undue concern for technical fidelity—every endeavour will, however, be made to ensure the vehicle looks and feels realistic. This will enhance crew simulations and maximise its publicity value. It will build upon the technical design work already completed for Project Marsupial, particularly allowing testing and validation of concepts for vehicle fittings.

Development of the HOP will involve:

(a) obtaining a second-hand 4WD vehicle;
(b) modifying the vehicle to satisfy Mars Analog Rover Initiative specifications;
(c) outfitting the vehicle with appropriate interior and exterior fittings;
(d) addition of a lightweight, painted cosmetic shell representative of the Wombat cabin;
(e) planning and execution of a series of outback campaigns in close coordination with Operation Red Centre, the MSA project to establish MARS-2 (Mars Australian Research Station).

2.2 Project Lifecycle

The HOP lifecycle spans approximately five (5) years, by which time an electric platform is planned to be operational. Basic elements of this lifecycle are shown in table 2.2.1. A 12-month design and construction phase will be followed by an initial 2-4 week campaign of in September 2001. A period of evaluation and refinement of the vehicle will follow this first operational campaign. A second campaign (up to three excursions) will be undertaken during the period April to September 2002. Further development of the project will subsequently follow the same pattern, alternating between evaluation and refinement, and operational campaigns.

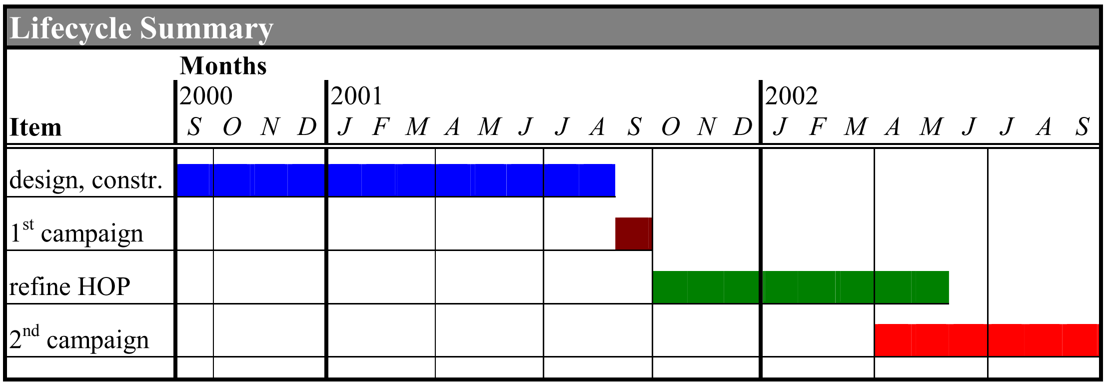

Table 2.2.1. Project lifecycle to September 2002.

This timeline is driven by two primary constraints: the need for rapid mobilisation of a human operations platform to build on momentum achieved by the Mars Arctic Research Station, and simulations in Australian Mars analog environments being best undertaken during the southern hemisphere winter (mid year).

Further details on the HOP schedule can be found in section 3.2.

2.3 Costs

Budget Totals		
Category		**Costs**
Vehicle Mods.	$	12,900.00
Key Electrical Systems	$	2,100.00
Communications	$	7,900.00
Life Support	$	800.00
Internal Fittings	$	2550.00
Furniture	$	350.00
Consumables	$	495.00
Science Systems	$	4,800.00
Miscellaneous	$	5,100.00
Grand Totals	$	36,995.00

Table 2.3.1. Budget totals by category.

The HOP is intended to be a low-budget project, enabling the Mars Society Australia to engage in analog operations in the short term. A fully-functional analog rover can be developed on a budget of approximately US$20,300, or AU$37,000. Unlike the United States, where the aerospace industry provides fertile conditions for mounting private, volunteer-based technical projects, the lack of any major space commitment in Australia presents a challenge to securing initial support.

We are confident that initial successes generated with Mars Society seed funding will lead to a long term, sustainable local funding base via sponsorship, membership subscriptions, personal donations and possible government grants. We suggest the HOP represents a low-risk investment for the Society, since we have already mobilised the expertise, workforce and detailed plan to deliver a high quality platform within 12 months.

A summary of the vehicle budget is provided in table 2.3.1. A detailed breakdown of the costs for the HOP can be found in section 3.3.

2.4 Science Objectives

The study of Mars analog locations can serve as a proxy for the study of Mars itself, as demonstrated by the NASA Haughton-Mars Project[1]. This kind of study will help define the operational specifications for the HOP.

Realistic Mars field experiments, observations and sample collection will be performed during the HOP testing

3. HOP Project Organisation

3.1 Work Breakdown Structure and Management

The HOP Work Breakdown will be grouped under Design, Resources and Marketing tasks. This structure is displayed in figure 3.1.1.

A Project Manager (focussing on logistical issues) and an Assistant Project Manager overseeing design tasks will liaise closely with the MSA National Technical Director.

The Design Team will be responsible for vehicle acquisition, modifications, fittings, and operations specifications. The Design Team has three subsections, Electrical Systems, and Platform and Vehicle Operations, each under the control of a manager. The Design Team will also manage the construction of the vehicle and its components.

The Resources Team will ensure that the project has adequate resources, both human and financial. It has two subsections: Financial, under the management of a Finance Officer, and the Human Resources (HR), which will be overseen by the Project Manager.

The Marketing Team will be managed by a Marketing Officer, and will be charged with developing promotional materials for the HOP for both sponsors and the public, and with managing media relations for the project.

[1] http://www.arctic-mars.org/

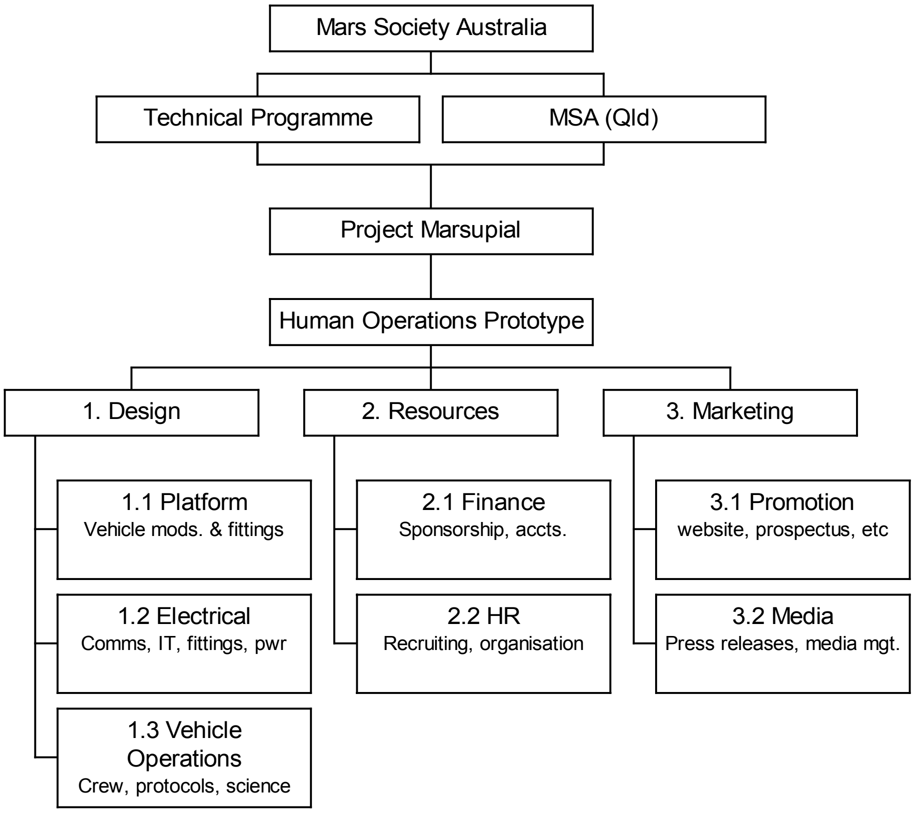

Figure 3.1.1. Work breakdown structure for the HOP

All appointments to official positions will be provisional for 3 months from the date of appointment. Current appointments are as follows:

Project Manager: Ben Cairns, <einre@uq.net.au>
Assistant Project Manager: Andrew Fenton, <s362908@student.uq.edu.au>
Finance Officer: *vacant*
Marketing Officer: *vacant*
Electrical Systems Manager: Ian Clough, <i.clough@mailbox.gu.edu.au>
Platform Manager: Matthew Clark, <s354037@student.uq.edu.au>
Vehicle Operations Manager: Llewellyn Mann, <suneag1e@hotmail.com>

3.2 Schedule

Apart from logistical tasks, such as project planning, and sponsorship and other funding efforts, which will be ongoing, the initial project schedule may be broken into four main phases, as given in section 2.3. These phases and their attendant tasks are explained below, and are summarised in table 3.2.1.

The vehicle design and construction phase will comprise fittings and vehicle structural and cosmetic design, followed by vehicle modifications and outfitting. Cosmetic modifications will be performed as the last component of the construction of the vehicle.

An initial campaign in an Australian Mars-analog environment will follow the completion of the vehicle, but will be backed up by campaign design carried out in tandem with the design and construction of the rover.

A period of project evaluation and refinement will begin after the initial campaign, identifying the achievements of the project to date, and the aspects of the project which require refinement. Design of modifications to the vehicle and their construction will proceed as necessary, as will a refinement of the campaign design.

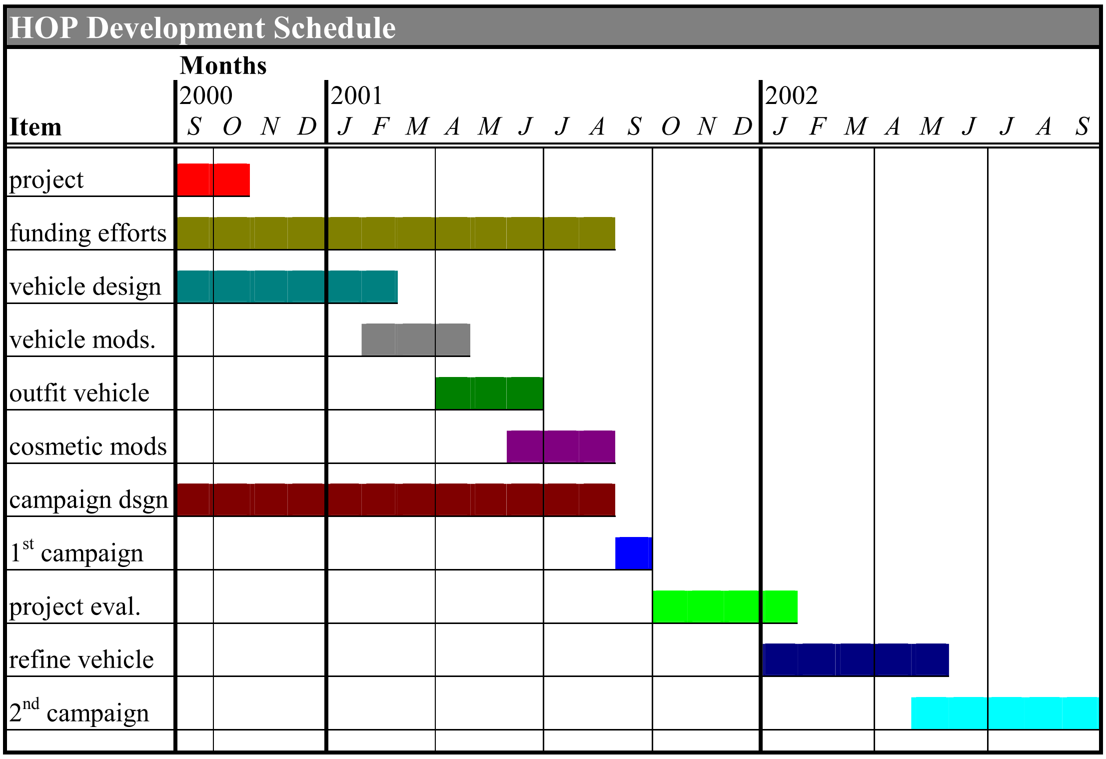

Table 3.2.1. HOP development schedule to September 2002.

These refinements will be further tested in a second operational campaign, consisting of one or more excursions to Australian Mars-analog environments.

Note that the purchase of a base vehicle is not included in the above schedule. A Mars Society Australia supporter, Col Grant, has donated a second hand Mitsubishi L300 Express 'Starwagon' to the Mars Society Australia for use as a base vehicle. The vehicle is only 2WD, and estimates of the commercial cost of converting the Starwagon to 4WD are in the range AU$4,000 to $5,000. The Starwagon variant of the L300 Express is designed to function as a passenger (rather than utility) vehicle, and has a higher roof in the rear section of the cabin.

However, while the donated Starwagon is not 4WD, versions of the same model vehicle that are 4WD are readily available. An additional, 4WD L300 may be purchased for AU$6,000 to $7,000. The preferred option is to maximise our assets by purchasing a second vehicle, leaving the donated Starwagon to serve as a pre-prototype for early testing of concepts, and ultimately as a source of spare parts. If a suitable vehicle cannot be purchased, the donated Starwagon will be adapted to suit the off-road requirements of the project.

3.3 Budget

The project budget has been calculated by incorporating quotes and estimates on the various vehicle modification requirements and fittings, and estimates on the cost of an initial campaign of two weeks. Contingency funding of 15% of development, construction and outfitting costs is included to cover possible inaccuracies in the quotes and estimates.

Platform Components		
Category	**Item**	**Cost**
Vehicle Mods.		
	4WD mods or 4WD vehicle purchase	$ 6,000.00
	air-conditioning, if retro-fitting required	$ 1,000.00
	off-road tyres	$ 400.00
	suspension	$ 500.00
	cosmetic shell	$ 4,000.00
	painting/signwriting	$ 1,000.00
Subtotal (AU$)		*$ 12,900.00*

Table 3.3.1. Platform cost breakdown.

Electrical Systems		
Category	**Item**	**Cost**
Key Vehicle Electrics		
	additional 24V alternator	$ 200.00
	extra lighting	$ 300.00
	winch	$ 600.00
	24V wiring systems	$ 200.00
	solar panels	$ 500.00
	extra batteries	$ 300.00
Communications		
	computing (laptops and/or PDAs)	$ 6,000.00
	hand-held radio (hire 2 wks) *	$ 800.00
	satellite phone (hire 2 wks) *	$ 400.00
	HF radio (hire 2 wks) *	$ 100.00
	GPS	$ 600.00
Life Support		
	refrigerator	$ 600.00
	ventilation fan	$ 100.00
	water pump	$ 100.00
Subtotal (AU$)		*$ 10,800.00*

Table 3.3.2. Electrical systems cost breakdown.

A breakdown of costs by product or service category is given in tables 3.3.1 to 3.3.4. The total amount of the budget is AU$36,995 (US$20,317.65 as at 1 October 2000). Of this, AU$31,700 comprises development, construction and outfitting costs, AU$1,795 are campaign costs, and AU$4,500 is contingency funding.

A number of development and campaign costs are assumed to be mitigated in full or in part by the participants self-funding or donating their time and the use of assets available to them. These include:

- the use of computer and other equipment to assist in the design process;
- time spent by project team members on design and construction work;
- the provision of most consumables for the initial campaign by the participants. (not including fuel and specialist items for consumption by the rover crew during testing).

Vehicle Operations		
Category	**Item**	**Cost**
Internal Fittings		
	storage fittings (includes external)	$ 300.00
	water storage	$ 150.00
	kitchen unit	$ 500.00
	toilet unit	$ 1,500.00
	non-human waste storage	$ 100.00
Furnishings		
	bedding	$ 100.00
	seating	$ 50.00
	work areas	$ 200.00
*Consumables**		
	food	$ 80.00
	hygiene supplies	$ 15.00
	medical supplies	$ 150.00
	fire extinguisher	$ 50.00
	fuel	$ 200.00
Scientific Equipment		
	geological	$ 800.00
	biological	$ 500.00
	meteorological	$ 500.00
	other	$ 3,000.00
Subtotal (AU$)		*$ 8,195.00*

Table 3.3.3. Vehicle Operations cost breakdown.

Miscellaneous Items		
Category	**Item**	**Cost**
Miscellaneous		
	cooking and eating utensils	$ 50.00
	leisure equipment (playing cards, etc.)	$ 50.00
	insurance	$ 500.00
	contingency funding (15% development costs)	$ 4,500.00
Subtotal (AU$)		*$ 5,100.00*

Table 3.3.4. Miscellaneous cost breakdown.

Other in-kind donations will be sought from Society members and interested individuals where possible, to reduce the cash requirements of the project.

Note that it is also prudent to add some contingency funding to the project. The budget will be increased by 15% to allow for contingencies.

Note that items marked * are required only during operational campaigns. These campaign costs may be distinguished from the development and construction costs.

3.4 Project Funding

Funding for the HOP will have three primary sources: the Mars Society, sponsorship as cash or in-kind support, and donations of time and resources by project volunteers. Each of these is further detailed below.

Priority for seeking sponsorship and donations for the various categories of required items (examples are vehicle modifications, electrical equipment, or consumables) will be allocated according to the funding needs of each category. Figure 3.4.1 displays the data from table 2.3.1, and shows the funding requirements for each category under the projected budget.

3.4.1 The Mars Society

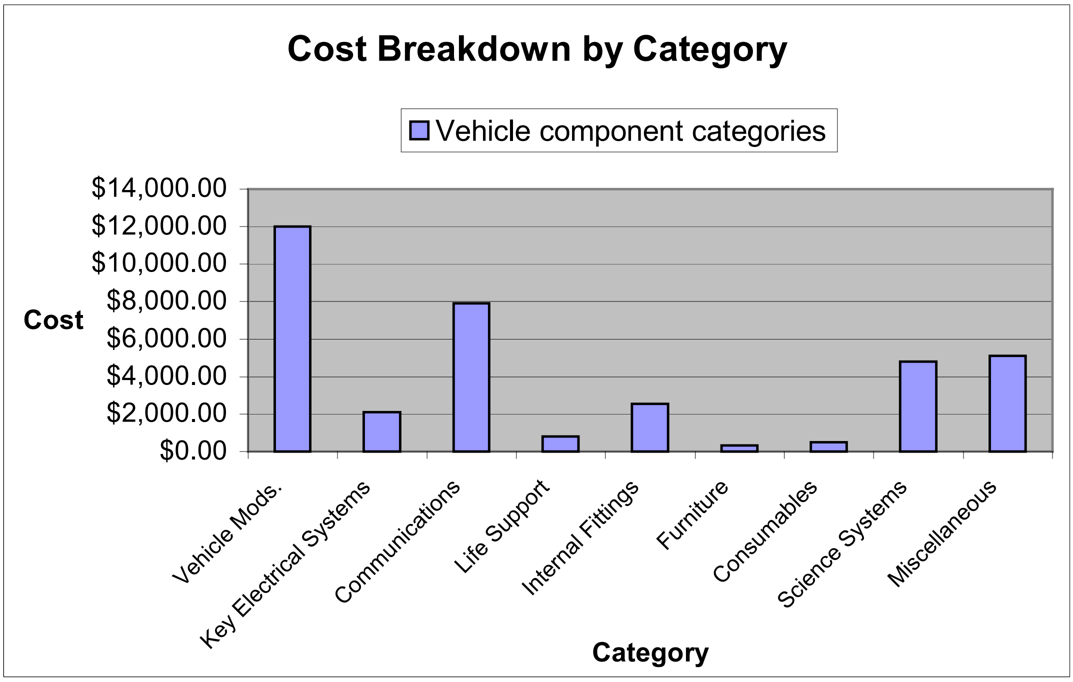

Figure 3.4.1. Comparison of costs of HOP component categories.

In support of teams contributing to its Mars-analog Rover Initiative, the Mars Society is offering cash support of up to US$10,000. With current exchange rates in favour of the US dollar, this is equivalent to an amount up to approximately AU$18,000—more than 50% of the projected budget. Such seed funding would be allocated in part to the initial development of Project Marsupial and its prototype, and thus to attracting further sponsorship.

The Mars Society's financial support is therefore very important to the project, removing a large portion of the financial pressures and demonstrating a clear commitment by the Mars Society International to the Mars-analog operations and the Society in Australia. Establishing a link between the Mars Society's existing, successful record of Mars-analog operations at the Flashline Mars Arctic Research Station, and future Australian Mars-analog operations would also be invaluable for attracting sponsorship to the HOP, Project Marsupial and other Mars Society Australia technical projects.

3.4.2 Other Sponsorship

Although the Mars Society may provide a considerable part of the funding requirements for the HOP, other sponsorship is also essential to the project. Sponsorship can provide cash, materials and expertise to the project, and will help raise the profile of the HOP, Project Marsupial and the Mars Society Australia. Sponsorship will also help forge the sponsorship relationships required to enable larger projects, including the continued technical development of Marsupial.

Sponsorship targets include:

(a) corporates in the telecommunications, Internet, automotive and components industries for cash sponsorship and/or equipment;
(b) small business manufacturers for construction, repairs and modifications;
(c) university-based research centres.

It should be noted that small to medium enterprises (SMEs) are the primary target of the HOP project's sponsorship efforts. SMEs with national clienteles are the most likely organisations to benefit from exposure as sponsors of the HOP.

Larger organisations are more difficult to penetrate in order to have proposals heard, and the HOP is also more likely to come up against competition for sponsorship funding, especially after the media exposure given many sports after the Sydney 2000 Olympic Games. On the other end of the scale, businesses in the state of Queensland that are without a significant proportion of interstate clients are unlikely to benefit from the exposure generated by the HOP.

Thus, while the amount that individual sponsors will contribute are reasonably small given the likely national exposure of the project, sponsorship positions will be most attractive to national SMEs.

3.4.2.1 Sponsorship Opportunities

The following sponsorship packages are available to organisations for the Project Marsupial Human Operations Prototype (HOP).

Principal Sponsor (one only)

- Naming rights for the vehicle, ie. the *[Principal Sponsor's Name] Marsupial HOP*.
- The name, *[Principal Sponsor's Name] Marsupial HOP*, used to refer to the vehicle in all printed and on-line Project Marsupial publications, and prominent on the vehicle itself.

- Principal Sponsor's name and logo prominent on all printed and on-line Project Marsupial HOP publications.

Major Sponsors (two max.)

- Major Sponsors' names and logos prominent on the vehicle.
- Major Sponsors' names and logo prominent on all printed and on-line Project Marsupial HOP publications.

Other Sponsors

- Other sponsors and in kind donors will be recognised in printed and on-line Project Marsupial HOP publications.
- In-kind donations which may assist with the design, construction or operation of the vehicle are also sought, and will be gratefully accepted.

Note that all alternative sponsorship proposals from potential Principal and Major sponsors will be seriously considered

3.4.3 Individuals

While no significant financial support for the project should be required of project team members, it is hoped that the Mars Society Australia can generate a certain amount of backing for the project through its members. This support may be as cash donations, or as parts and labour on the project. As previously noted, the project has already received the unsolicited donation of a vehicle, demonstrating support amongst the membership for the Society's technical goals.

Donations of time and labour, particularly, are valuable resources that the HOP will require as a volunteer endeavour. Donations of parts and materials may also be available from individuals, however these will not be aggressively pursued. Individuals may be expected to contribute only as their means and desires allow.

Cash donations by individuals may also provide some funding to the project, however major project components should not require funding from this source. Cash donations by individuals might best be employed to enable non-critical project components (which would not otherwise be possible) to be finished in time for the initial operational campaign in September 2001.

4. The HOP Design

As stated in 3.1, the HOP design tasks are organised in three divisions: Electrical Systems, Platform, and Vehicle Operations. The following sections and the appendices outline the design of the HOP for each of these divisions.

It should be noted that the design of the HOP remains to be completed. Although further work must be done in order to refine the design before construction, the relatively small scale nature of the project allows that construction need not be a lengthy process, and sufficient time is available to complete construction before September 2000 (see the development schedule in section 3.2).

4.1 The HOP Platform

The Platform Team will design and oversee the construction of all structural and mechanical modifications and additions to the base vehicle. Appendix P discusses the platform design in detail.

4.2 Electrical Systems

The Electrical Systems Team will design and implement all modifications and upgrades necessary for effective functioning of the vehicle and any electrical / electronic / communications equipment used in Project HOP. Appendix EX explains the electrical systems requirements for the HOP in more detail.

4.3 Vehicle Operations

Vehicle operations include the control of the rover, activities carried out inside the rover, and the scientific tasks associated with the use of the rover, and will be the responsibility of the Vehicle Operations Team.

A report outlining the scientific and human operations of the HOP is included in this proposal under Appendix VO. As the main emphasis of the project, the scientific aspects of the rover are vitally important to the validity of the analog, and the report considers geological, biological and meteorological objectives. The human aspects of the mission are also examined in order to make the mission as realistic an experience as possible for the crew, and to ensure their safety. It must be noted that at this time, the operational parameters given in this report are primarily a guide and first approximation. They will develop with scouting missions to analog sites, consultation with experts, and through international collaboration.

5. Project Team

The HOP team is currently:

- *Ben Cairns*; Project Manager. (University of Queensland)
- *Matthew Clark*; Platform Manager (University of Queensland)
- *Ian Clough*; Electrical Systems Manager(Griffith University)
- *James Cole*. (University of Queensland)
- *Michael Day*. (University of Queensland)
- *Andrew Fenton*; Assistant Project Manager. (University of Queensland)
- *Arran Haydon-Clark*. (Queensland University of Technology)
- *Jason Hoogland*; Mars Society Australia Technical Coordinator and Project Manager, Project Marsupial. (University of Queensland)
- *Jamil Khan*. (University of Queensland)

- *Llewellyn Mann*; Vehicle Operations Manager (University of Queensland)
- *Brett Robertson*. (University of Queensland)
- *Sulaiman Thompson*.
- *William Twyford*.

We are actively seeking to expand our team with:

(a) Scientists in the areas (see Appendix VO):
    (i) field geology;
    (ii) biology, palaeobiology, or exobiology;
    (iii) meteorology;
(b) Individuals with public relations and marketing skills;
(c) Individuals with financial management skills;
(d) Individuals with mechanical skills;
(e) Individuals experienced in 4WD operation;
(f) Enthusiastic people willing to play a part in this exciting venture.

Our primary goals are to fill managerial positions (see 3.1), from whence managers will assemble their teams and proceed with the project.

While most of the HOP team is based in Queensland, Australia, we are particularly interested in attracting interstate and international team members. For example, MSA members in South Australia are assisting in the selection of Mars-analog sites. Collaboration between the Queensland team and other, geographically separated groups will provide the HOP with the greatest knowledge base from which to draw expertise on the various vehicle systems.

This is particularly the case as concerns the operation of the vehicle. Test protocols for this are to some extent able to be developed independently of the development of the vehicle, require few financial resources, and would therefore suit international collaboration.

5.1 Contact Details

The HOP project aims to encourage collaboration between geographically separated groups and individuals, both within Australia and internationally. Those who are interested in participating in the project should contact:

Ben Cairns,
Project Manager, HOP
E-mail: einre@uq.net.au
Phone: +61 7 3876 0080
Mobile: +61 407 743 498

Andrew Fenton,
Assistant Project Manager, HOP
E-mail: s362908@student.uq.edu.au

General enquiries about Project Marsupial or the technical programme of the Mars Society Australia (MSA) may be directed to the MSA's Technical Coordinator, Jason Hoogland:

E-mail: hoogland@mech.uq.edu.au
Phone: +61 7 3365 4251

The latest version of this document may be found through the Mars Society Australia's website, http://www.marssociety.org.au/, by following the links to Project Marsupial.

6. Glossary

2WD: Two-wheel drive.

4WD: Four-wheel drive.

Analog Operations Research: Research into crew protocols and procedures for a Mars mission, undertaken in a Mars analog environment.

EVA: Extra-Vehicular Activities. Those activities performed outside the pressurised region/s of HOP and which would require the use of protective suits.

HOP: Human Operations Prototype.

Mars Society, The: A non-profit organisation based in Colorado, USA, with international branches including the Mars Society Australia (MSA). The Mars Society supports the human exploration and eventual settlement of the planet Mars through public, political and private activities.

Mars analog: Generally relates to simulation *of* or *in* Mars-like environments on Earth

NASA: National Aeronautics and Space Administration of the United States of America.

Appendix P—Platform

1. Proposed Base Vehicle

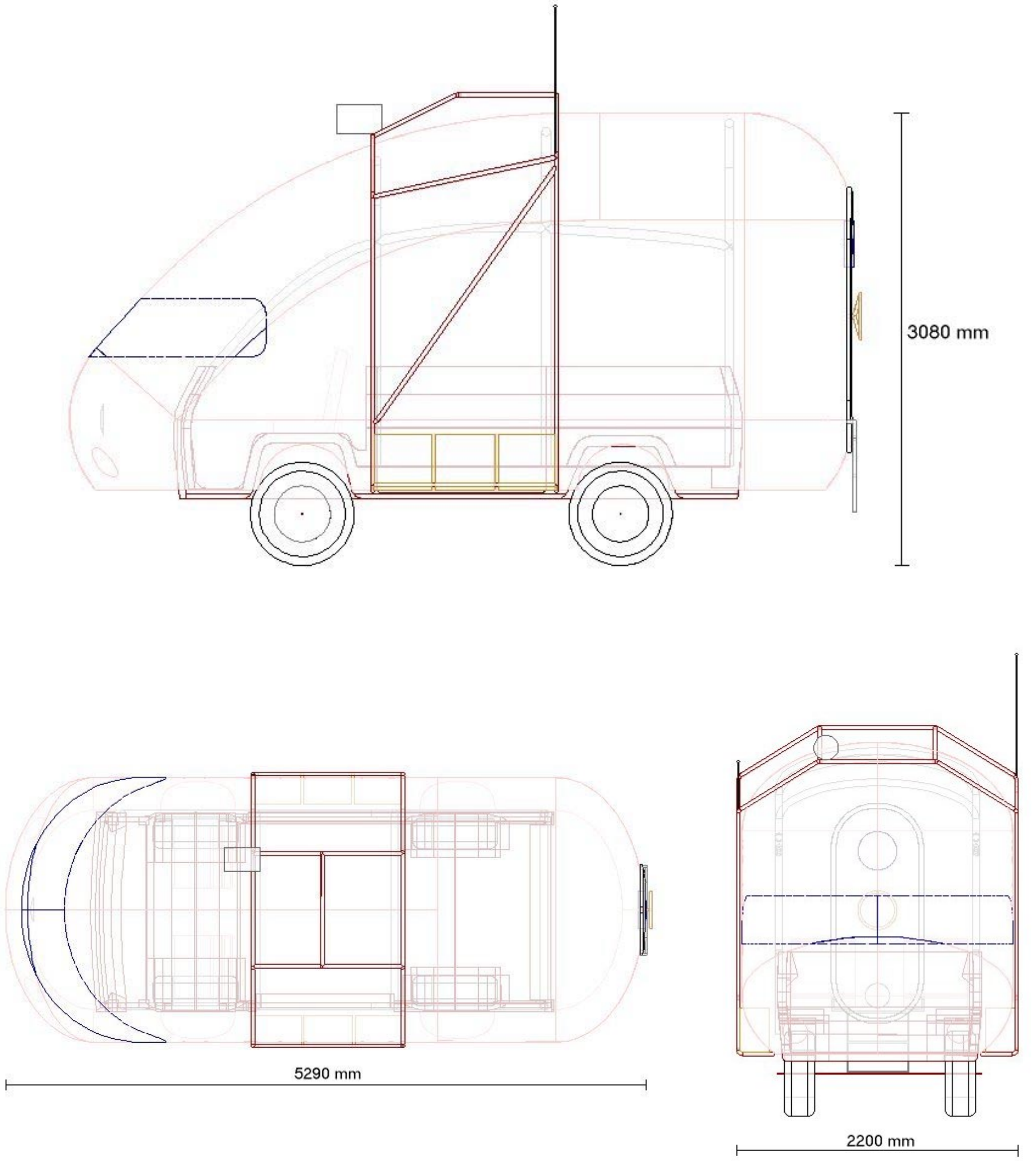

Figure P.0. Views of the HOP design, with dimensions.

As discussed in the main document of this proposal, the HOP will be based on an existing production vehicle. The criteria used for selecting a base vehicle are as follows:

(a) **Off road capability;** it must:

- be a part-time or full-time 4WD, or be able to be converted to a 4WD

- have sufficient ride height (clearance)
- have adequate shock-absorbers and suspension
- Be able to handle low range for long periods of time.

(b) **Acceptable mass**, preferably such that the total mass is close to the 1.5 tonne specification.
(c) **Adequate range;** it must be able to travel 320 kilometres one way.
(d) **Adequate internal space;** it must have at least 4 cubic metres of space for a crew of two.
(e) **Compliant with desired modifications;** it must be able to be easily modified to fit the HOP concept.
(f) **Inexpensive;** the vehicle should be either donated or second hand.

Figure P.1. The approximate dimensions of the original vehicle.

Based on these criteria, the HOP is being designed as based on a 4WD van from the Mitsubishi L300 range. These vehicles are the most readily available second hand 4WD van in the Brisbane area, and can be bought for approximately AU$6,000 (for a 1985-86 model). The specifications for this vehicle are shown in table P.1.2. A rendering from a 3D model of the vehicle shows an approximate original configuration (figure P.1).

As stated in section 3.2 of the main document, a Mars Society supporter has donated a 2WD L300 'Starwagon'. This vehicle will be used to refine the design of the HOP in the early stages, and will also provide spare parts for the 4WD vehicle. It may also be possible use the donated Starwagon as the HOP vehicle, if 4WD modifications can be made without excess expense. Current quotes do not indicate that such modifications would be prohibitively expensive. However, the project's assets will be maximised by the purchase of a second vehicle, the total cost of which would be approximately the same as modifying the donated Starwagon.

1.1 Vehicle Structure

1.1.1 Tyres

Five off road tyres will be purchased which will have sufficient terrain capability.

1.1.2 Suspension

It is hoped that the base vehicle will come with a suitable suspension system, but an enhanced suspension system (such as heavy-duty shock absorbers) may have to be considered.

1.1.3 Chassis

The chassis of the base vehicle need not be in perfect condition, as structural enhancements (see section P.1.1.4.6) are already included in the design. It is expected that significant saving could be made on an appropriate base vehicle if it has some degree of surface corrosion other blemishes. The appearance of the chassis is not significant, as the outer shell (see section P.1.1.4) will cover it entirely.

1.1.4 Pressurised envelope / Body

The outer shell has been designed to fulfil two requirements:

(a) To make the vehicle look like a Mars rover
(b) To provide sufficient internal space for the crew and fittings.

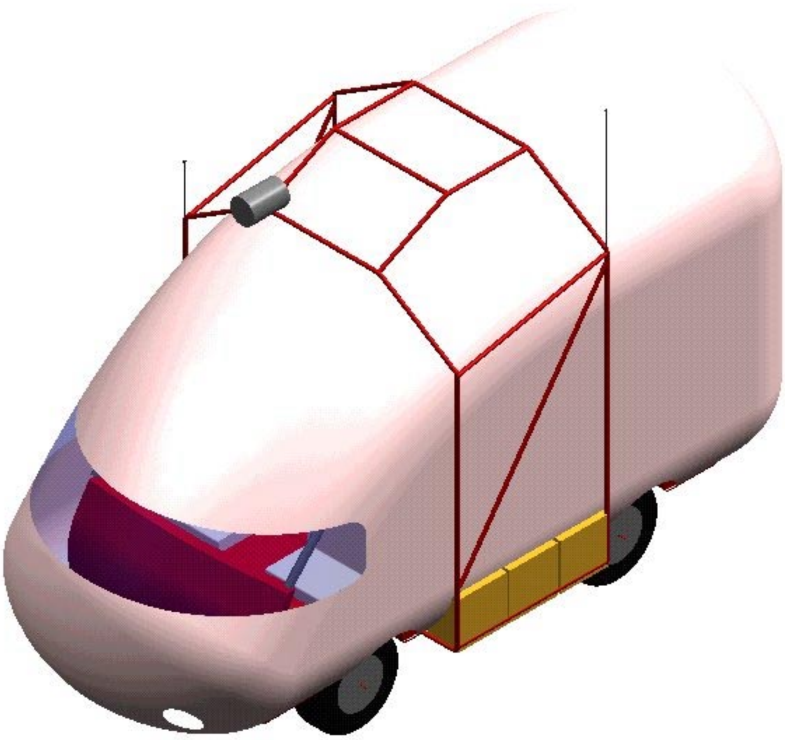

Figure P.2. The pressure envelope or shell.

The shape of the shell is based on the design of the Wombat variant described in the Mars Society Australia's initial proposal for Project Marsupial, and is adjusted where necessary to fit the chassis of the van. The shell design is shown in figure P.2.

These modifications are an important aspect of the prototype vehicle. The modifications made to the vehicle are given in section 1.1.4.6.

1.1.4.1 Shell Material

a) Shell
The HOP exterior will be constructed out of foam sandwich which consists of a light weight closed-cell PVC foam, with layers of Epoxy Resin and a fibre glass matrix bonded to either side. The structure will be made using conventional foam sandwich construction techniques.

Foam thicknesses vary depending on the strength desired however for a structure such as this a 5mm or 8mm foam will most probably be used. 20-ounce layers of fibreglass on either side of the foam should be sufficient.

There are several benefits of using a foam sandwich shell for the exterior of the HOP. The shell can be constructed with varying strengths depending on where it is most required. The desired shape can also be achieved with relative ease. The separation of the internal and external layers means that the foam will also have some insulating properties The sandwich construction also provides good stiffness, better than just a fibreglass structure. Fibreglass has good strength in tension but is relatively poor under compressive loads. The separation in layers overcomes this problem to some extent.

b) Windscreen
Another important aspect of the shell is the window at the front. The window need not be a structural component of the shell, and it need not be designed to withstand high-speed impacts. For these reasons, a lightweight clear plastic such as polycarbonate or perspex is the most likely choice of material.

1.1.4.2 Construction

a) Shell
An initial mould will be designed to suit the shape desired for the exterior. A simple mould can then be formed using a basic skeletal structure of wood or other similar materials, which are easy to work with and shape. The closed cell PVC foam sheets are placed over this mould and tacked to the structure. They are then joined with Epoxy Resin based glue. At this point, the outside layer of fibreglass is layed. The amount of fibreglass required will vary, depending on the strength and the stiffness required. Once the outside layer of fibreglass has cured, the shell can be lifted from the mould and then the inside layer applied in a similar fashion.

b) Windscreen

If costs permit, the curved shape can be custom fabricated, but the preferred option is to obtain an existing screen of adequate dimensions, such as is seen on the front of many speedboats. Alternatively, the curve could be achieved by using 5 or 6 flat sections of the plastic material.

Further investigations will be conducted into the most effective solution. It should be noted that a curved windscreen of a shape similar to that shown in figure P.2 is much more difficult to fabricate, but this design is favoured simply because it makes the vehicle look more like a mars rover.

1.1.4.3 Attachment

It is intended that the shell be attached to the frame by bolting it to metal plates, which can be welded to the bottom of the chassis. It will also be supported at the top by the structural supports (see section 1.1.4.6). The shell is not designed to take any of the structural loads. Rather, added structural supports on the original chassis will provide the necessary strength. To ensure that bending and torsional forces in the body are not transmitted into the shell, analysis of the vehicle will ensure that the effective stiffness of the body is greater than the effective stiffness of the shell structure. When this is confirmed to be the case, then the yield stress of the shell material and the stress concentration at the bolts joining the shell to the main chassis will not be as critical.

Care will be taken to ensure that the envelope is well sealed to simulate a ‘pressurised’ environment, to assist in insulation, and to keep the inside as clear from dust as possible. Silicon or rubber seals should be sufficient for this purpose.

1.1.4.4 Mass

It is estimated that a reasonably strong shell will weigh between 50kg and 75kg.

1.1.4.5 Cost

The cost of such a structure will be between $3000 and $4000 depending on the specific design of the shape that is required.

1.1.4.6 Structural Modifications

As well as the addition of an outer shell, structural modifications to the vehicle itself will be necessary.

As can be seen in figure P.3, the cabin of the wagon will be cut away at window level, increasing the space available to the crew. So that the strength and stiffness of the chassis are not compromised, 'roll bars' will be added to the vehicle (also shown in figure P.3). These are regularly custom fabricated and welded to the frame by workshops specialising in off-road vehicle modifications. These modifications may also be performed in collaboration with a Technical And Further Education (TAFE) college to reduce costs.

Figure P.3. Structural modifications to the base vehicle.

Attachment points will also be added on both sides of the chassis so that external storage containers and other fittings may be added to the structure.

1.1.5 Pressure Ports

The vehicle will include an airlock located at the rear. The airlock door will be fitted into the shell, as shown in figure P.4.

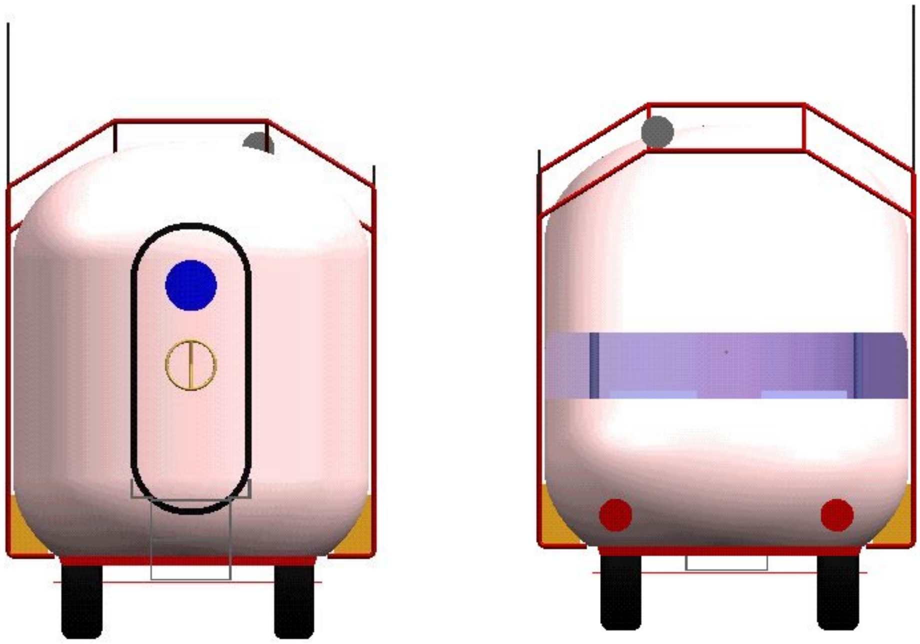

Figure P.4. Rear and front views of the HOP.

1.2 Power Plant

Mitsubishi L300 Express 'Starwagon' Specifications	
Component	*Description*
Engine description	Four cylinders, in-line, SOHC, cast-iron block, alloy cross-flow head, balance shafts.
Cylinders	4cyl
Valves per cylinder	2v
Capacity	2351
Compression ratio	8.5:1
Maximum power	81kW (DIN) @ 5000rpm
Maximum torque	182Nm (DIN) @ 3500rpm
Fuel system type	PFI (petrol fuel injected)
Fuel tank capacity	55 litres
Transmission description	Five speed manual Four-wheel drive.
Front brake description	Ventilated discs
Rear brake description	Drums
Rim material	Steel
Front tyre description	215 SR15
Rear tyre description	215 SR15

Table P.1.1. Specifications for Mitsubishi L300 Express 'Starwagon'

The power plant consists of the Starwagon's engine, supplemented by solar panels. The engine specifications are given in table P.1.1. As specified in Appendix EX, this system will be fitted with a 24-volt alternator, in addition to the 12-volt alternator already available on all vehicles. Note that the donated Starwagon has a petrol engine.

1.3 External fittings

Most external fittings will be fixed to a small frame surrounding the central portion of the cabin. This frame is not intended to take significant stresses, but rather to add utility to the vehicle by providing numerous attachment points for fittings.

The external fittings for the rover are those outlined in the specifications. They include a winch on the front of the rover, hidden by a hatch. This will be secured to the front of the chassis to provide a strong support attachment. Sample stowage is also needed in the specifications and is provided by compartments built in to the shell. These will be accessible from the outside, as well as the inside, doubling as a simulated sample pressure port. Equipment stowage spaces will also be built into the shell to house various tools that the crew will need on an EVA. Robotic systems, such as a boom for the ground penetrating radar system and a manipulator arm, may also be added as time and budget allows, as these are not heavy items.

1.4 Internal fittings

A guide to the space required for the internal fittings can be seen in table P.1.2. As this table demonstrates, only approximately one third of the volume of the vehicle will be occupied by fittings, with other items moveable to allow flexible use of space.

Internal Fittings Dimensions				
Item	**Width (mm)**	**Depth (mm)**	**Height (mm)**	**Volume (m^3)**
Total crew space	1900	3000	2100	**12**
Toilet	670	400	950	0.25
Kitchen unit	650	380	var	0.52
Work areas	600	400	n/a	0.5
Instrument Storage	1000	500	1000	0.5
Other Storage	var	var	var	0.75
Sleeping (x 2)	600	1800	500	1.08
Waste Storage	1000	500	300	0.15
Total storage				3.75
Remaining space				**8.25**

Table P.1.2. Dimensions of internal fittings.

Note in table P.1.2: *var* indicates that values are variable and will be sized to accommodate as much space as possible within the confines of the vehicle; *n/a* indicates values that are not applicable. Volume values for fittings with variable dimensions are estimates designed to indicate an upper bound on volume.

2. Vehicle performance

2.1 Speed

The vehicle will satisfy the speed requirement 32.5 kilometres over easy terrain. As it will be heavily modified, the vehicle may be geared down from its standard, road-worthy configuration, such that it does not unnecessarily exceed the specification and create a hazard.

2.2 Range

The vehicle will operate within a one-way range of 320 kilometres, as per specifications. The standard fuel tank has a capacity of 55 litres. This is insufficient to satisfy the range requirements; while additional fuel capacity will be added if possible, for a prototype vehicle this limitation will not be significant, and refuelling will be possible without a great reduction of simulation realism.

2.3 Vehicle mass

The weight of the original chassis is approximately 1.2 tonnes. The combined dry weight of the modified platform will be approximately 1.6 tonnes.

2.4 Terrain

The donated Starwagon has a clearance of 250mm, while 4WD vehicles. The HOP will be capable of maintaining 8 kilometres per hour over rough terrain.

2.5 Logistics

The vehicle fits within the envelope that is required of a packed width of 9'-0" (2.7m), height of 8'-6" (2.6m) and length of no more than 24'-0" (7.3m).

2.6 Crew

A crew of two is the maximum allowable for the HOP, due to logistical and volume requirements. While extra crewmembers might be accommodates.

Appendix EX—Electrical Requirements

1. Introduction

In order to have a successful trial of the HOP Interim Rover it will be necessary to ensure that proper electrical, electronic, communications and monitoring systems are installed in the vehicle.

The key areas will involve core vehicle electrics, life support, internal equipment power, external equipment power, communications, recharging capabilities and any ancillary equipment.

Furthermore, the key scientific processes that will be carried out on a daily basis must be identified, as must their respective electro-support requirements.

The internal and external physical environments must be considered and from part of key considerations for location, power, vibration, IP ratings, portability etc. These will obviously overlap with the role of vehicle design/modifications, with direct input from the Science team.

Of particular concern is the type of long range communications equipment needed for effective communications at the intended Mars analog sites, giving regard to signal absorption by the physical environment. The HOP team has approached communications suppliers such as Motorola, Telstra, and Olbis, to determine signal 'blackspots', and this information will be incorporated into the design of the HOP's operational campaigns.

Purchasing equipment need not be our only option, as some equipment could be borrowed, hired, donated, hire-purchased. Sponsors or auctions may also be a good source. The budget for the electrical systems components is given in section 3.3 of the main document.

1.1 Core Vehicle Electrics

1.1.1 24 Volt Alternator

A 12-volt system may not be sufficient for all types of equipment needed for the trials. 24 volts is a very common second standard, providing supply to fittings requiring the extra voltage. An additional alternator (and wiring, see below) will be included to satisfy this requirement.

1.1.2 Extra Lighting

The standard internal and external lighting fitted to our current base vehicle is not sufficient for off road/remote area operations and will be augmented to provide an adequate working environment in and around the vehicle.

1.1.3 Winch

A winch will be fitted to the HOP for emergency use. A manual winch may be included in the equipment carried by the vehicle as a failsafe.

1.1.4 24 Volt Wiring System

As mentioned above, an extra reticulation system would be necessary for any 24-volt operations.

1.1.5 Solar Panels

Considering the available solar radiation, a non-fossil-fuel option should be considered for recharging, low-noise radio operations and any electrical requirements that may be hindered by the presence of motor emissions. Solar panels will also provide a renewable back-up supply for emergency conditions.

1.1.6 Extra Batteries

The operating environment and the 24-volt alternative power system require additional batteries to support continuous and reliable supply of power to critical systems. Energy storage requirements will be identified and a battery system will be included that satisfy these requirements.

1.2 Life Support

1.2.1 Refrigerator

Although non-perishable foods are preferable for trials, some first aid supplies and medicines would need refrigeration. A small Peltier refrigerator is capable of maintaining such perishable supplies without great power requirements, and is included as an optional fitting.

1.2.2 Water pump

A water pump is necessary to transport water from the potable water tank to outlets. A wide range of brands and models are available that are specifically intended for use in vehicles, and it is not anticipated that any difficulty obtaining or fitting an appropriate pump will be encountered.

1.3 Internal equipment power

It is expected that most internal equipment will operate from the installed 12-volt system.

1.4 External Equipment power

This will be determined to a certain extent by the scientific and operational requirements of the HOP, and may involve a mixture of 12 volt and 24 volt systems. Power outlets will be fitted and labelled accordingly.

1.5 Communications

Australia is an island continent. It has continuous coastal areas, large arid inland areas with small populations, and has a total land area approximately equal to North America.

With a population of only 18 million, the population density is small and hence infrastructure in many areas is very low level. Safe communications are a continuing challenge. These reasons (among others) also make it an ideal choice for Mars-analog sites. It is possible to drive reasonable distances for up to four (4) days and still be in the same state or territory.

Due consideration for remote proximity, great distances from populated areas and signal loss guide the choice of options for communications.

1.5.1 Computing Equipment

Computer equipment, primarily laptops, will be provided to crewmembers for data entry, storage, and communications purposes. Ideally, one laptop will be provided to each of the crew, but budgetary constraints may limit this to one laptop between the two crewmembers, although scheduling of usage may mitigate this disadvantage.

Personal Digital Assistants (PDAs) may also be provided to the crew to represent EVA data storage and retrieval capabilities that may be available to the crew of an actual Mars mission. If budgetary constraints permit, these may be wirelessly networked with computer systems on-board the vehicle to allow maximum flexibility to crewmembers on EVA.

1.5.2 Mobile Radio System

A mobile communications system may involve voice-operated-switching personal communicators fitted to the headsets of the operators or than actual hand-held units.

1.5.3 Satellite Phone

A satellite phone unit would be invaluable for documentation purposes and for reporting locations for any emergencies or calls for assistance. The cost of purchasing a satellite phone is too large to justify as an expenditure for the HOP, however hire of satellite phones is cost effective over purchase for periods much longer than the operational campaigns intended for the HOP.

Satellite Phone (hire)	$200.00/wk
Satellite Phone (purchase)	$4000 - $6000

Due to the nature of the physical environment and the distance from mobile telephone repeater stations, satellite phone is the only viable option for mobile-phone style communications, but is expensive to purchase and air-time is costly (about $2.00/minute).

Antarctica and the Arctic Circle are the only major regions not effectively covered by satellite phone, and hence this item is suitable for use with the HOP in Australian Mars-analog environments.

1.5.4 Global Positioning System

A GPS is a mandatory requirement for both safety and scientific purposes. Properly integrated with computer and communications systems, a GPS will provide important tracking and documentation data.

1.5.5 HF Radio

High-frequency (HF) radio is commonly used in remote Australian locations and is often the only system (apart from satellite phone) available for communications. HF Radio offers an effective voice communications System and radio modems would allow inexpensive data communications.

The Royal Flying Doctor Service (the rural Australian medical service) can be contacted by HF Radio and can reach any location if needed for emergencies.

1.6 Recharging Equipment

There are three main options.

(a) On-vehicle charging (alternators)
(b) Portable generators
(c) Solar electricity

The choice of option will depend on the equipment and operating environment.

1.7 Ancillary equipment

Other equipment may be required for scientific operations, and these will be added to the electrical systems requirements as necessary.

2. Physical environments

It is anticipated that dust will be a significant problem; all necessary sealing will take place. Conversely, moisture is highly unlikely to pose a major problem in the arid regions of Australia's Mars-analog locations, but the possibility of spillages by the vehicle crew must be taken into account.

Vibration will be considered on an item-by item basis to develop a global installation requirement. The portability of certain electrical systems will necessitate a variety of placement, stowage and securement options, and locations will be determined on a safety and priority basis.

Appendix A—Vehicle Operations

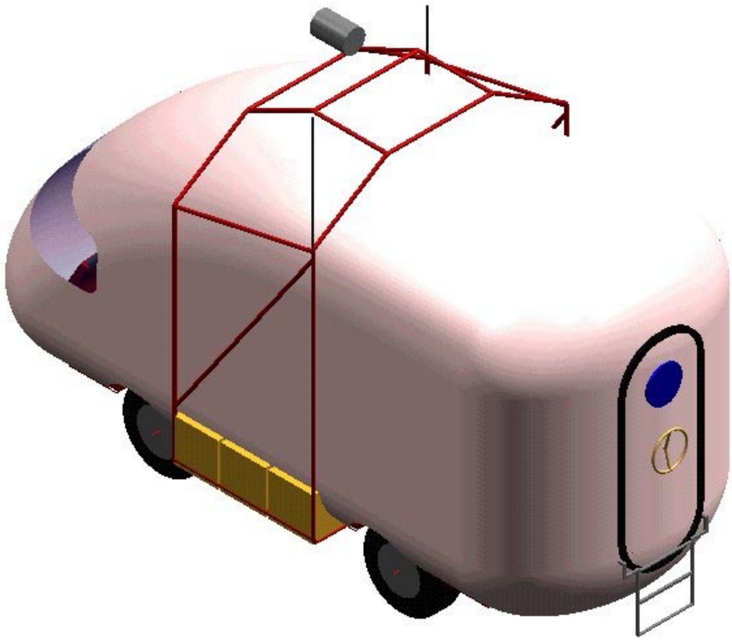

Figure A.1. Rear isometric view of the HOP.

1. Introduction

This appendix discusses the requirements for the operation and use of the HOP, which will drive the development of vehicle operations specifications and standards. Detailed vehicle operations specifications, developing which is the task of the project's Vehicle Operations Team, will include protocols for all activities, as well as a daily program of events, and standards for the use of facilities, including sleeping, eating and ablutions. Activities common to all manned space situations are largely covered by existing NASA standards[2]. However, the development of specifications tailored to the operation of Mars rovers is a prerequisite for their use, and is the primary goal of the Analog Rover Initiative.

2. Objectives of Analog Missions

Analog missions have two primary components: scientific operations and human factors research.

2.1 Human Factors

The human factors of a pressurised rover are of particular interest, and a primary result of tests of the analog rovers will be human factors data. This data will drive the development of actual (non-analog) pressurised rovers. In the case of Project Marsupial, data from tests of the HOP will assist with the development of the electric platform.

[2] Specifically, NASA-STD-3000B

2.2 Science Operations

The scientific operations of a Mars-analog mission involve both Mars-analog research, furthering our understanding of Mars by studying terrestrial analogs, and studies for terrestrial sciences that are intended to represent activities (eg. botany, zoology, meteorology and geology).

Hence the scientific program of HOP will seek to develop studies to satisfy two objectives, (a) accurately simulating the scientific activities of a real Mars mission, and (b) provide such simulations under the constraints of the analog test environments.

3. Analog Mission Sites

The choice of Mars-analog sites for the initial missions of the HOP will be driven by a variety of factors.

Australia's "Red Centre" presents a wide range of locations with significant visual similarity to the Martian surface. The region around Birdsville, in the state of Queensland, and extending into the north of South Australia, includes significant stretches of red, sandy, and/or rocky desert, including the Lesser Sandy Desert, Sturt's Stony Desert, and the northern Flinders Ranges. Some areas are also relatively free of vegetation, adding to the realism of the simulation if carried out there.

Realistically, a wide variety of terrain is likely to be encountered within the range of the rover, some of which will be largely unsuitable as Mars-analog sites (eg. seasonal creek beds lined with vegetation), and sites should be chosen that place the most suitable terrain within return range of the rover. While a variety of locations must be within this range, initial campaigns, prior to the development of an Australian Mars-analog research station, may focus on the human factors of pressurised rovers, and this will be the immediate focus of the Human Operations Prototype.

4. Science Activities

The potential sciences discussed below present a diverse basis for the HOP's science platform, not including the human factors of the vehicle. The choice of fields (geology, biology and meteorology) reflects the primary scientific activities of the crew on an actual Mars mission: the study of Mars and its geological and climatic past and present, and the search for life.

4.1 Geology

Geological studies include basic geological surveys of the area, and a number of particular examinations of sites of interest, to be determined by initial surveys.

One major element of the geological study of Mars is the search for water, either liquid or as ice. Liquid water is, on Earth, a sufficient condition for the presence of life, and liquid water on Mars would be associated with the highest chance for the discovery of life.

However, unless a crew is exploring Mars' polar regions, liquid water and ice exist only beneath the surface. Sites suspected to contain significant amounts of water can be studied with Ground Penetrating Radar (GPR), which analyses the return of an electromagnetic signal emitted into the ground to determine the structure of the ground beneath the surface. Although permafrost and other potential Martian water features will not be available in Australian Mars-analog environments, the use of GPR systems to study water tables and other subsurface geological features will adequately represent their use in an actual Mars mission.

However, certain aspects of terrestrial geology may be directly related to features that might be found on Mars. These include geothermal springs, a type of feature that may contain liquid water and potentially life. Should Mars have had a warm, wet past, as suggested by current theories of its geologic history, sedimentary deposits may be found which might contain fossils of past Martian life. The Australian region in which Mars-analog tests will occur was once the floor of a shallow sea, and includes fossilised stromatolites (a primitive colonial form of life). Both fossilised stromatolites and geothermal springs have been studied in the region by NASA-sponsored Mars-analog researcher, Malcom Walters. Dr Walters has been, and will continue to be consulted on the selection of test sites and suitable Mars-analog research activities.

Many features of the local geology are also suitable targets for study, with varying degrees of relevance to the study of Mars, including the water content of the soil, erosion processes, and salinity of the water table.

4.2 Biology

While the search for past or present life on Mars is a major goal of the study of the planet, a simple "search for life" is trivial on Earth—life can be found in even the most barren Mars-analog locations. Nonetheless, a number of biological investigations may be undertaken that are relevant to the test sites, and provide useful examples of how field science may be adapted to a pressurised rover context. It is important, however, that biological studies not simply be "make work" assignments, and the choice of studies will be driven to some extent by the expertise of the campaign team.

Microbiological studies of the soil would provide a reasonable sample collection and study analog. While this form of soil study is unlikely to be productive in the Martian environment (as evidenced by the negative results from the Viking programme soil experiments), it will provide a context in which samples may be taken and stored on-board or examined inside the rover.

A basic survey of the flora and flora in the region would also be appropriate, as an Australian Department of Environment and Heritage (DEH) survey of the flora and fauna of the Flinders Ranges is due for completion in 2000. Data from the DEH survey may be crosschecked against species encountered by the rover crew to provide a simple follow up to the study.

4.3 Meteorology

The atmospheric conditions, such as the temperature, pressure, wind velocity and direction, at the Mars-analog test site will be measured and recorded as they would be during an actual Mars mission. Meteorological observations will be automated to the extent that this does not add significant costs to the project budget. This passive observation of local meteorological conditions has limitations, of course, and active observation, such as with the use of weather balloons, would be a part of operations on Mars.

As much as possible, meteorological studies will be carried out in conjunction with Australian meteorologists and the Bureau of Meteorology.

5. Human Factors

As has been stated, human factors research will comprise the initial focus of the HOP. Whilst care will be taken, during design and construction, to provide comfortable and functional accommodations inside the rover for the crew, a thorough investigation of their interaction with the rover and the Mars-analog environment is necessary to provide the groundwork for a more realistic rover design.

It is important that research into the human factors of a pressurised rover be carried out so as to produce valid and publishable results. This is important directly to supporting a future manned Mars mission, and also to the credibility of the Mars Society. As there are few local scientists with human factors experience in space science, international collaboration in the design and execution of human factors studies will be vigorously pursued. To this end, the Mars Society Australia proposes the formation of a vehicle operations or human factors working group as part of the Analog Rover Initiative.

5.1 Crew Facilities

5.1.1 Life Support System

Life support systems are an important consideration for the design of the analog mission. The requirements for life support will influence all aspects of the mission, including the design of the operations, the rover's facilities, and the supplies and equipment that will be required. Clearly, the life-support requirements for a mission at an Australian Mars-analog site will differ from those of a mission to Mars, however those that will impose constraints on the behaviour of the crew, such as the airless external environment, will be simulated.

5.1.1.1 Pressurised Envelope

The most significant limitation on the crew will be that they will not be able to leave the vehicle (except in non-simulated emergency circumstances) without preparation for EVA. For a crewmember to leave the vehicle without prescribed EVA preparations would be for them to perish in the simulation, and this will place stresses on the crew of great importance to the human factors of the rover.

5.1.1.2 Waste Disposal

As per the design requirements for the analog rover, there must be facilities to contain and store liquid and solid wastes for one week.

A small "Porta Potti" unit, similar to those commonly used in recreational vehicles (RVs), will provide storage of human wastes. The unit incorporates storage for waste materials in cassettes that may be replaced as necessary.

Non-human waste, primarily as a product of food preparation, will be stored, and removed to the external storage in the course of normal EVA actitivities.

5.1.1.3 Water Supply

Humans require 2 litres (L) of drinking water per day under normal conditions, giving a minimum requirement of 28L of water for two crew on a one-week mission. However, it is recommended that those travelling through the desert regions of the "Red Centre" carry with them 5L of water per person per day for all activities. As the crew will be relatively active under specialised Mars-analog conditions (eg. wearing Mars-analog spacesuits), 6L of water will be allocated to each crewmember per day. This gives a total requirement of approximately 85L. Water storage tanks of up to 100L volume are readily available for RV applications.

5.1.1.4 Heating, Ventilation and Air Conditioning

As the potential analog sites are desert environments, systems must be provided to make the cabin comfortable during the extreme heat of the day and extreme cold of the night, including air conditioning and heating systems. Easy ventilation of the cabin must also be available for safety purpose, and a fan will be included to provide for this requirement.

5.1.1.5 Dietary Needs

Specific diets will be designed for the mission, taking into account environmental factors and the energy requirements of the crew. The rover's limited storage space suggest that foodstuffs will be more compact and have higher energy-to-volume ratios will generally be favoured. As standard human factors dictate, the psychological impact of the appeal, or lack thereof, of foodstuffs must also be considered.

5.1.1.6 Medical Requirements

Adequate medical supplies and equipment must also be available, and all crewmembers trained in applying first aid. Serious medical emergencies will warrant the suspension of the simulation until the situation is resolved; situations will be evaluated if and when they occur. Medical waste will be properly disposed of, separately to other waste.

5.1.2 Furnishings

The rover will include internal furnishings for the following: storage of general items; items requiring tailored fittings/storage (such as fragile scientific equipment); food preparation; seating; sleeping and hygiene facilities.

5.1.2.1 Food Preparation

Required facilities for food preparation will include food storage areas, food preparation areas, and refrigerating facilities.

5.1.2.2 Sleeping Facilities

The limited internal space of the rover mandates that the crew bedding does not take up valuable work or storage space when not in use. To this end, the bedding should be capable of being either easily stowed away, or used to serve a dual purpose, such as a table or bench area.

5.1.3 EVA Systems

EVA will form a significant aspect of a Martian mission, as it will be required for many of the important tasks such as performing many of the experiments and searching for signs of present or past life. To gain experience with the human factors of Mars EVA conditions and operations, EVA equipment (such as a planetary spacesuit equivalent and an airlock equivalent) will be included in the mission design, along with operations for gaining experience with using them. As the primary goal of the mission is to gain experience with operations, the obvious temperature differences between an analog site and a Martian site are not a significant issue. However, the temperature of the analog environment, particularly the heat, will limit the scope of the EVA activities that will be able to be performed, so as to avoid potential problems such as dehydration.

5.1.4 Work Areas

Equipment and work areas, some of which may also serve other, non-science needs, will be required. The nature of these will be determined by the science operations that will be conducted during the mission. Details of these operations are listed above in this Appendix.

5.1.5 Leisure Facilities

Rest and leisure activities will be an important part of the crew's schedule, and this must be taken into consideration in the planning of the mission. Working in confined spaces, remote locations, and hostile locations are not unique to Mars, however procedures and protocols may be adapted from other situations in which people have faced similar conditions, such as on space stations, or in environments such as Antarctica. The analog mission provides an opportunity to tailor these procedures and protocols to better cater for a Martian environment.

5.2 Operations and Procedures

5.2.1 Daily Itinerary

A complete daily itinerary will be required for the mission, based upon the science program and the specifics of the chosen site. As a primary goal of the mission is to learn about operations by gaining experience and testing out ideas, the itinerary should be flexible, and it should be noted there is the possibility that it will be adapted during the mission if current itineraries prove inadequate.

5.2.2 Safety Guidelines

Safety will be critical on Mars; it is also an important concern for an analog mission, particularly because the candidate sites are in remote areas. While the safety of the crew in the Mars-analog environment will the primary concern in developing appropriate guidelines, the considerations influencing the design, and the design itself, will provide useful groundwork for future missions. Safety equipment will include medical supplies (as above) and appropriate fire extinguishers.

5.2.3 EVA Guidelines

As with an actual mission, guidelines for conducting EVA's will be developed when the details of the types, locations and duration's of the EVA's have been developed.

6. Cost Estimates

The costing estimates and breakdowns for the vehicle operations are given in section 3.3 of the main document. These estimates include a budget for internal fittings and some basic science systems and equipment. It should be noted that in many cases, the actual requirements are difficult to assess—many items of equipment may be available on loan or as superseded items from educational institutions.

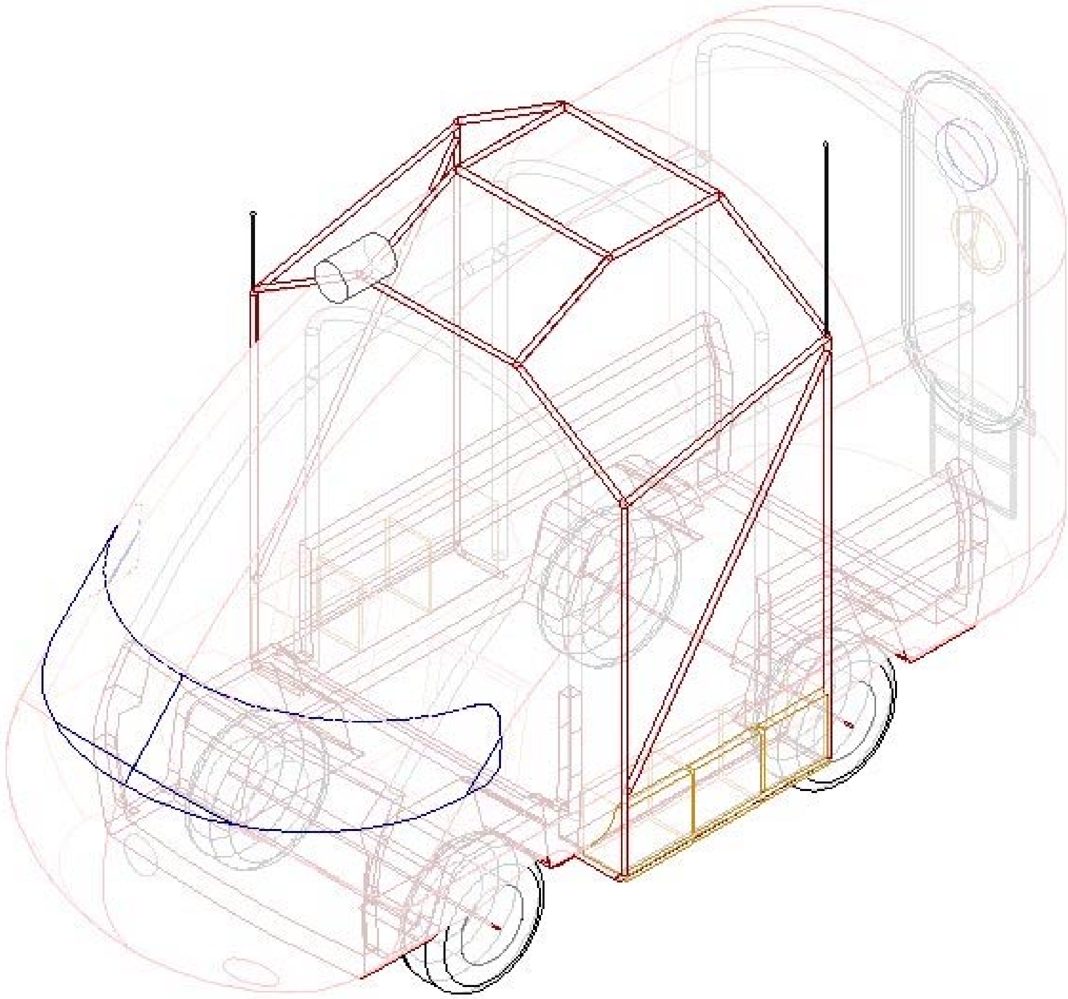

Figure VO.1. Wireframe diagram of the HOP.