Martian Designs

Final Design Report

MARS-OZ Design Project

MARS-OZ ANALOGUE RESEARCH STATION SUBSYSTEM RESEARCH AND DEVELOPMENT PROJECT

MARTIAN DESIGNS – 18TH NOVEMBER, 2011

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Project Start Date	25 July 2011
Project Finish Date	18 November 2011

THE AUSTRALIAN NATIONAL UNIVERSITY

Mars Society Australia

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1. Executive Summary

The MARS-OZ research and development project involved the design of a series of subsystems which are to be incorporated into the design of a Mars mission crew habitat simulation module that is to be located in the Arkaroola region of South Australia.

This Final Design Report (FDR) document has been compiled to provide a detailed explanation, description and justification of the final design solutions proposed by Martian Designs for the MARS-OZ habitat. The proposed designs include:

- A unique internal wall panel system
- A folding bed/desk arrangement
- A new upper deck cabin layout
- An incinerator for waste processing
- An incinerating toilet for human waste disposal
- A photovoltaic system to provide power
- A backup power system

System designs have been checked and verified against the original client requirements and specifications to ensure high quality design solutions. For continuing work, the FDR outlines design specifications that should be recognised and adhered to by future designers, manufacturers, contractors and occupants of the habitat.

The design specifications provided are combined with detailed protocols and processes that should be followed to ensure safe and efficient operation of the provided design solutions. This guarantees the longevity of the system and maximises the derived value of the designs provided and the habitat as a whole.

A preliminary estimate of expected costs has been provided for the benefit of the client. It is expected that a reasonable and realistic portion of the overall budget will be used on crucial habitat aspects such as water and waste management, air conditioning, privacy and some power generation.

The design solutions provided by Martian Designs were developed with consideration toward their final system integration. To this end, the integration network between these systems and the MARS-OZ habitat is provided. This demonstrates that the provided designs integrate effectively with the other systems in the habitat.

To date, the design team has performed adequately, as measured by the meeting of deliverable deadlines and completion of the project within the budget constraints. Moreover, the high quality of design provides the customer with a complete design concept that can be immediately utilised by the client for the final habitat design.

2. Introduction

2.1. Project Mission Statement

Mars Society Australia proposes to conduct a variety of extra-terrestrial analogue research experiments in the Arkaroola region of South Australia. This involves human habitat simulation using the prospective habitat, called MARS-OZ, as the central research test facility. An initial design has been proposed for MARS-OZ including structural engineering and the preliminary interior layout; however, the current design lacks the engineering design and detail for vital support services including power systems and waste management. The design of interior spaces is another aspect requiring further analysis and design so as to maximise the efficiency of the facility's operation.

The crew habitat module and the support services are essential elements for a future Martian outpost. These systems must facilitate the wellbeing of the crew and provide an environment that supports the safe and efficient performance of tasks. It is the goal of this project to address the identified design deficiencies using an integrated systems approach. In conjunction with the objectives stated by the client, we have developed the following *High-level Customer Needs Statement:*

- Subsystem design must accommodate an 8-member crew for up to one month.
- Subsystem design must meet the expressed guidelines for environmental factors, including restrictions on the upper/lower limits for radiation, heating, vibration, noise, and atmospheric composition.
- Design must meet all statutory engineering requirements and standards.
- The proposed subsystem designs must accommodate the mission objectives of exploration and research and respect the capabilities and limitations of the crew.
- The habitat must offer the crew amenity and safety and maximise productivity, whilst retaining cost-effectiveness in its design.

2.2. Document Purpose

The Final Design Report (FDR) is the tertiary document to be presented to the Client, Mars Society Australia. Upon presentation of the Final Design report to the Mars Society Australia, the project will subsequently be closed out. This document includes detailed design work developed by Martian Designs. The document outlines the design solutions to the MARS-OZ Habitat design tasks that were awarded to Martian Designs. These design tasks have been previously outlined in detail in the project scope documentation and the solutions proposed for these design tasks, which will be discussed in this document, have be thoroughly investigated and analysed in the Preliminary Sketch Plan (PSP) and the Final Sketch Plan (FSP) documents produced by Martian Designs.

Each design solution provides the following:

- An overview of the design
- Reasons for design decisions
- Design specifications to be met by MARS-OZ
- Detailed processes to ensure effectiveness of design
- Verification that the design meets all specifications (client based, pre-determined, Australian standards)
- A preliminary cost estimate

Martian Designs has considered how these designs are to be directly integrated and implemented into the overall plan for the MARS-OZ habitat. The FSP represents the final opportunity to obtain feedback on the designs before they are submitted to the client.

2.3. Current Progress

Completion of the FSP marked the realisation of the penultimate project milestone for Martian Designs and provided complete designs for the subsystems under consideration subject to finalisation. This document, the FDR, provides the finalised and completed designs for the subsystems of the MARS-OZ habitat investigated by the Martian Designs project team.

The final design phase has involved the transformation of pre-conceptual solutions to detailed conceptual designs. Designs have been repeatedly revised, with increasing levels of detail throughout the process.

The FDR is the final milestone of the MARS-OZ research and development project undertaken by Martian Designs, as commissioned by the Mars Society Australia. The completion and presentation of this document to the Mars Society Australia will mark the beginning of the closeout of the project. Finalisations of the design solutions, which are expounded upon in this report, were based on feedback obtained from the client. This Final submission includes detailed design and analysis of the chosen design options. Additionally, this FDR report Documentation is also accompanied by a brief project closeout statement.

2.4. The Project Team and Team Structure

The Martian Designs project team has been developed to best serve the diverse needs and functional system requirements of the project. The Martian Designs' project team can be seen below and further explanation of the team structure, personnel roles and communication channels may be found in Appendix IX: Martian Designs' Project Team.

The Martian Designs' Project team for the MARS-OZ analogue research station subsystem research and development project was as follows:

James Everdell - Project Manager

Jared Dean – Technical Manager and Design Team Member

Elliott Wise – Internal Architecture Group Leader

Sathyan Pooranachandran - Lead Designer

(Olivia) Jiazhen Zhu - Design Team Member

Alistair Watson – Water and Waste Management Group Leader

Charlie Boettcher - Lead Designer and Editor

Michael Gill - Design Team Member and Alliance Administrator

Rebecca Beasley - Design Team Member and Head Administrator

Phillip Watt – Energy Management Group Leader

(John) Hung Lui - Lead Designer

Emily Carrie - Design Team Member

Yifei Wang - Design Team Member

2.4.1. Organisational Chart

Figure 1 shows an organisational hierarchy outlining the Martian Designs team structure. It depicts the distribution of responsibility for internal team organisation (customer liaison, administration) and project design work (MARS-OZ sub-systems).

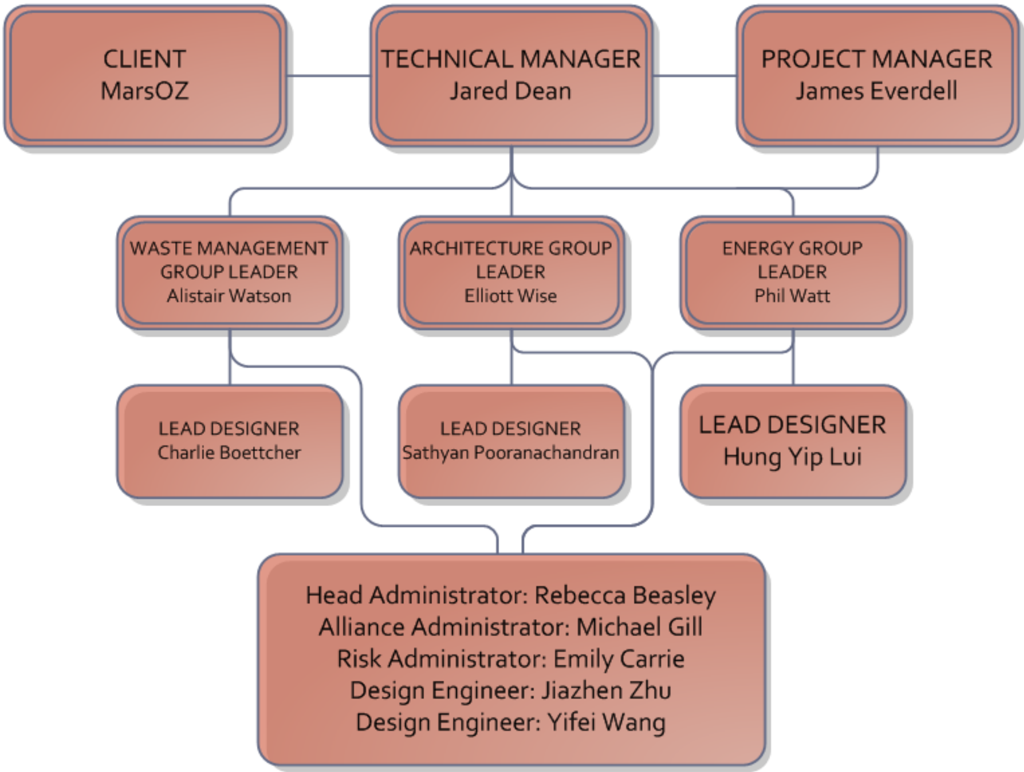

Figure 1: Design Team Structure

Project design engineers are allocated according to functional areas. There are three subsystems; Energy, Waste and Water, and Internal Architecture. Within these groups smaller sub-groups are formed to focus on distinct aspects within each system.

2.5. Project Stakeholders

The Mars Society of Australia (MSA) is the largest stakeholder in the project, with the second largest being the project team itself. The benefits for these stakeholders will be intellectual, scientific and eventually tangible. If the project is a success then it will have an impact on all facets of the MARS-OZ Analogue Research Station due to the scope of the project. If the MARS-OZ Analogue Research Station is subsequently deemed a success and obtains sufficient funding; then the subsystem solutions explored by this project may become components in the first ever manned interplanetary mission and interplanetary habitation. If this does become the case, then the stakeholders in such an event would extend past those directly involved with the project itself to the whole of society, with far reaching scientific discoveries and the extending of the human knowledge base.

Additionally other stakeholders whom have a vested interest in this project are the Australian National University (ANU), Liam Waldron and Lyle Roberts. Success in this project would not result in any compensation or tangible benefit to these stakeholders, however, it will add to their esteem.

3. Scope

Guided by structured systems engineering processes, the project was broken into the conceptually manageable subsystems outlined previously (Energy, Waste and Water, and Internal Architecture), each with individual subsystem scopes. These were carefully formulated to ensure the highest quality of design. The outlining of the system interface requirements of each of these is a crucial system-level task. This involves resolving interface discontinuities to ensure seamless integration of the subsystems. This interface analysis is conducted upon both the existing systems developed by MARS-OZ as well as those under current development. Below is an outline of the scope of each design team, which will be presented in more detail later.

3.1. Internal Architecture

The internal architectural considerations for the MARS-OZ habitat are crucial to the success of the project. The designs centre on maximising the effectiveness of the available internal space to derive enhanced crew productivity, comfort, and wellbeing. The scope of architectural consideration includes:

- A reconfigurable and collapsible bedroom structure
- Storage and room layout
- Fit out of sleeping cabins
- Analysis of human factors relating to the usage of the habitat
- Assisting in determining power and waste requirements

Major design influences include acoustic control, injury prevention, contamination prevention and the psychological wellbeing of the occupants of MARS-OZ.

3.2. Waste and Water Management

Waste management for this project will focus on the collection and processing of multiple waste streams within the MARS-OZ habitat. The waste streams considered include:

- Common organic materials (food and plant matter waste)
- Human waste (sewage)
- Plastics
- Non-hazardous contaminants
- Medical waste

Systems will be designed to enact the destruction of waste. The overarching goal of this system is to counterbalance waste generation whilst using minimal power and being simple to both use and maintain.

Grey water is another waste source requiring a processing system. Energy and material constraints imply that the reprocessing of water is imperative. Water recycling has considerable benefits towards the long-term sustainability and self-sufficiency of the MARS-OZ project.

3.3. Energy Management

The scope of energy management in the MARS-OZ habitat has been refined to ensure the quality and effectiveness of the systems in focus. Areas in which the energy management team will focus include:

- Power auditing to determine requirements
- Power generation
- Power load management
- Backup power systems

The energy system will be designed to maximise efficiency and effectiveness whilst minimising capital and maintenance costs. Considerations include external and internal temperatures, reliability, architectural and waste management needs, and ensuring transportability of the system.

4. Architecture

4.1. Introduction

The Internal Architecture sub-group of Martian Designs has concentrated on designing systems for the sleeping cabins in the MARS-OZ habitat. The focus throughout the design process has been on human comfort, in particular looking at ways to efficiently use the limited space available. As the occupants of the habitat will be working with one another for extended periods of time in confined quarters, providing them personal space is vital to the success of their research. One of the goals of the MARS-OZ project is to investigate the logistic and psychological issues imposed on occupants during a simulated Mars mission. The sleeping cabins play a key role in this experimentation. Flexibility and adaptability of systems within these areas is a necessity.

4.1.1. Scope

The scope of the Internal Architecture sub-group includes the design of two separate subsystems as well as a plan for the usage and overall layout of the sleeping cabin area.

One subsystem is a reconfigurable wall system for separating sleeping cabins from one another, and from the remainder of the habitat. The main functional requirements of this system are that it shall be capable of varying the number of rooms up to a maximum of 8, be able to be converted between single room and double room configuration, and be able to be converted to a completely open space thus extending the size of the living area.

The other subsystem is a combined bed/desk system to fit in each cabin. This is a response to MARS-OZ requirements that human factors are to be considered when designing the sleeping cabins. The system aims to provide some private living space beyond that of just a bed for each occupant.

Finally, MARS-OZ requires the sleeping cabins to accommodate up to 8 crew members. The habitat design published by MARS-OZ in the MS-3 document incorporates only 7 sleeping cabins. Accordingly, Martian Designs have provided an alternative upper deck plan that allows for an additional sleeping cabin. In doing so, the design team has ensured that only minimal changes to the existing design are necessary. Also provided is advice on both the usage of these systems and personal storage within each sleeping cabin.

4.1.2. Designs Considered and Final Choices

Initial design concepts for the inter-cabin wall system included large single panels and a concertina-style folding mechanism. Issues with these designs included difficulty manoeuvring them around the habitat, difficulty storing them, and mechanisms that were difficult to manufacture. For these reasons, among others, we chose to proceed with designing a system consisting of a number of removable panels.

For the combined bed/desk system the design team initially considered a number of off-the-shelf options, but these were found to be prohibitively expensive and incorporated superfluous features. Additionally, none of the investigated off-the-shelf options were able to conform to the unique spatial constraints imposed by the curved wall/ceiling. Since the mechanisms themselves were quite simple it was decided that a custom manufactured design process would be more appropriate as these could specifically accommodate these spatial constraints. Thus Martian Designs proceeded with an initial design concept for such a system.

4.2. Notes on Verification of Designs

For each system all specifications and constraints as determined in the Preliminary Sketch Plan have been consolidated. For each specification and constraint, the design team conceptually checked whether the design has met the requirement, and has given comments as to how this is done. Verification methods for confirming that the final product has met these requirements have also been provided. Because no actual product shall be directly produced by Martian Designs, these verification methods are intended for use by whomever Mars Society Australia chooses to source the final products. Martian Designs has however used the suggested verification methods wherever possible. Tables outlining the result of this verification process are given in Table 22: Combined Bed-Desk Specification Verification.

For the inter-cabin wall system Martian Designs produced a design that will likely meet almost all of the identified system requirements and constraints. One area in which the requirements of Mars Society Australia are only partially met, is in our chosen materials for the system. It was specified that the system be manufactured from wood, aluminium, or fibreglass. We chose to build parts of the system from steel to provide added rigidity and improve levels of safety. Another requirement which was only partially met was that the system is to have no sharp corners. Our design is capable of being manufactured such that there are no sharp corners, but this will add significant complexity to the manufacturing process. It was instead decided to simplify the process, and attempt to minimise the number of sharp corners. When the system is installed there are no protruding sharp corners. It is only during assembly, disassembly, and transportation of the system that these sharp corners may come into contact with humans. Finally, the level of soundproofing the designed system would provide was unable to be determined; however it is expected that the system will meet these requirements.

The combined bed/desk system also meets the vast majority of the identified system requirements. One requirement only partially met was that the system is to be easily transportable into and out of the cabin. The system is quite large and can only be partially disassembled. As with the inter-cabin wall system we also chose to incorporate steel into the design for added strength and safety. Finally we were unable to produce a system in which no sharp corners were present; however the finalised design has the number of such corners minimised.

Finally, the requirements that were identified relating to the overall configuration and fit-out of the sleeping cabin system all appear to have been successfully met by our designs.

4.3. Inter-cabin Walls

4.3.1. Chosen Design

After much consideration, it was decided that a design consisting of multiple interlocking panels was most appropriate for the inter-cabin walls. This design has no complex mechanisms and is simple to manufacture. Being modular it can be stored and transported with relative ease, and can also be moved about within the confined spaces of the cabin. Most importantly, it can meet the MARS-OZ requirement for re-configurability with little physical labour required. This is vital to the system's performance as bringing large system components into the habitat would be difficult.

Each wall in the chosen design consists of a number of horizontal panels designed to interlock and attach to non-permanent rails. The rails are to be mounted to the floors and roof. Each panel in the wall consists of two aluminium sheets mounted on long rods that protrude out of each end. These rods extend such that they may be placed on top on hooks attached to each rail. Figure 2 shows a complete system for one sleeping cabin.

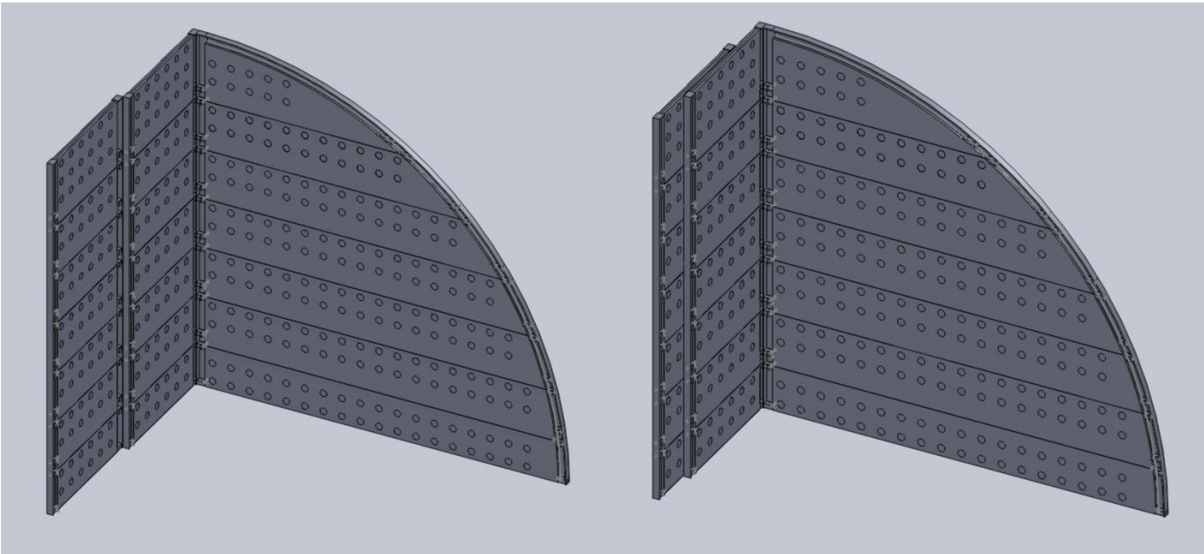

Figure 2: View of a Single Complete Room (Left: Door Closed, Right: Door Open)

For the walls between each bedroom and the corridor every panel is the same length. However, for the walls between bedrooms, the panels must follow the curvature of the outside wall of the habitat. To hold the panels, one of the rails is placed vertically in the corridor and the other again follows the curvature of the outside wall of the habitat. A more detailed view of the assembled panels for the walls between bedrooms is shown in Figure 3.

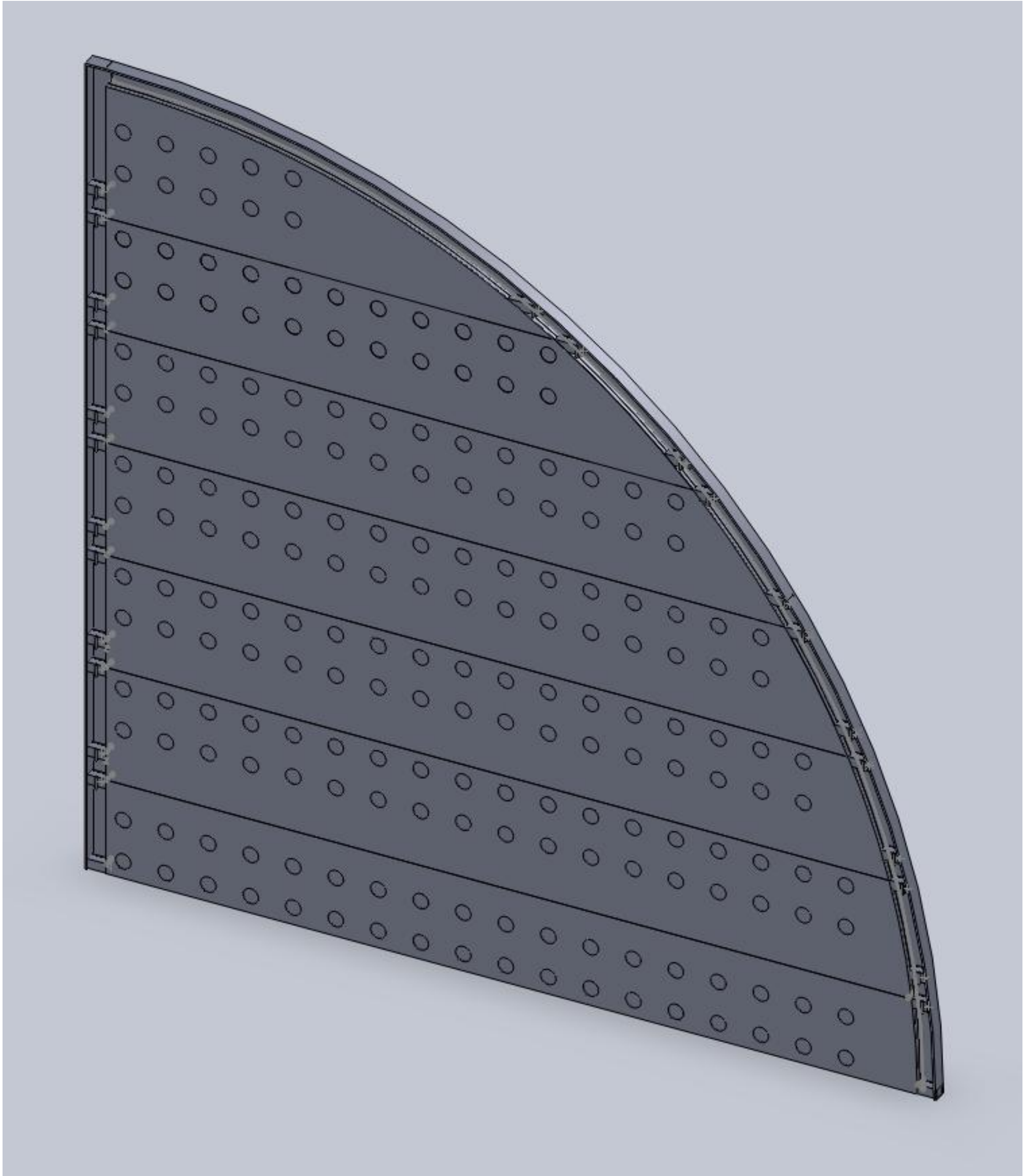

Figure 3: Wall Between Adjacent Sleeping Cabins

Soundproofing materials are sandwiched between the two aluminium sheets in order to provide acoustic insulation and maintain privacy. The two aluminium sheets in each panel are offset to partially overlap one-another. This means they can also partially overlap adjacent panels. The design allows for the only contact between adjacent panels to be made by soundproofing material. Additionally, all aluminium surfaces are to be perforated allowing sound to be absorbed rather than reflected within a cabin. The perforations shall not align on each side of the panel so as to prevent holes from accidentally forming through the wall. These considerations combine to form a robust method of maintaining privacy.

4.3.2. Components

The main components of this system are the walls, the rails, the sliding doors and the mounting points. The walls are composed of panels, while the rails are used to hold the panels in place and provide rigidity. The doors are also composed of panels and can be opened and closed by sliding them along rails mounted to the floor and roof. The mounting points are designed to fix each rail to the floor and the roof. Additional mounting points have been incorporated to allow for different room configurations and for the storage of walls by re-assembling them against other walls. These components are comprehensively described below.

Panels

Each panel is comprised of two aluminium sheets with Quiet Barrier® HD, a high density soundproofing material, sandwiched between. Additionally, two steel tubes run the length of each panel, between the aluminium sheets. These tubes are used for mounting the panels to the hooks on each rail and provide flexural rigidity to the system.

Each aluminium sheet is perforated to prevent sound from echoing within a sleeping cabin. This allows noise to pass into the soundproofing rather than reflecting off the aluminium. The sizes of the panels vary according to their location in the wall and door system.

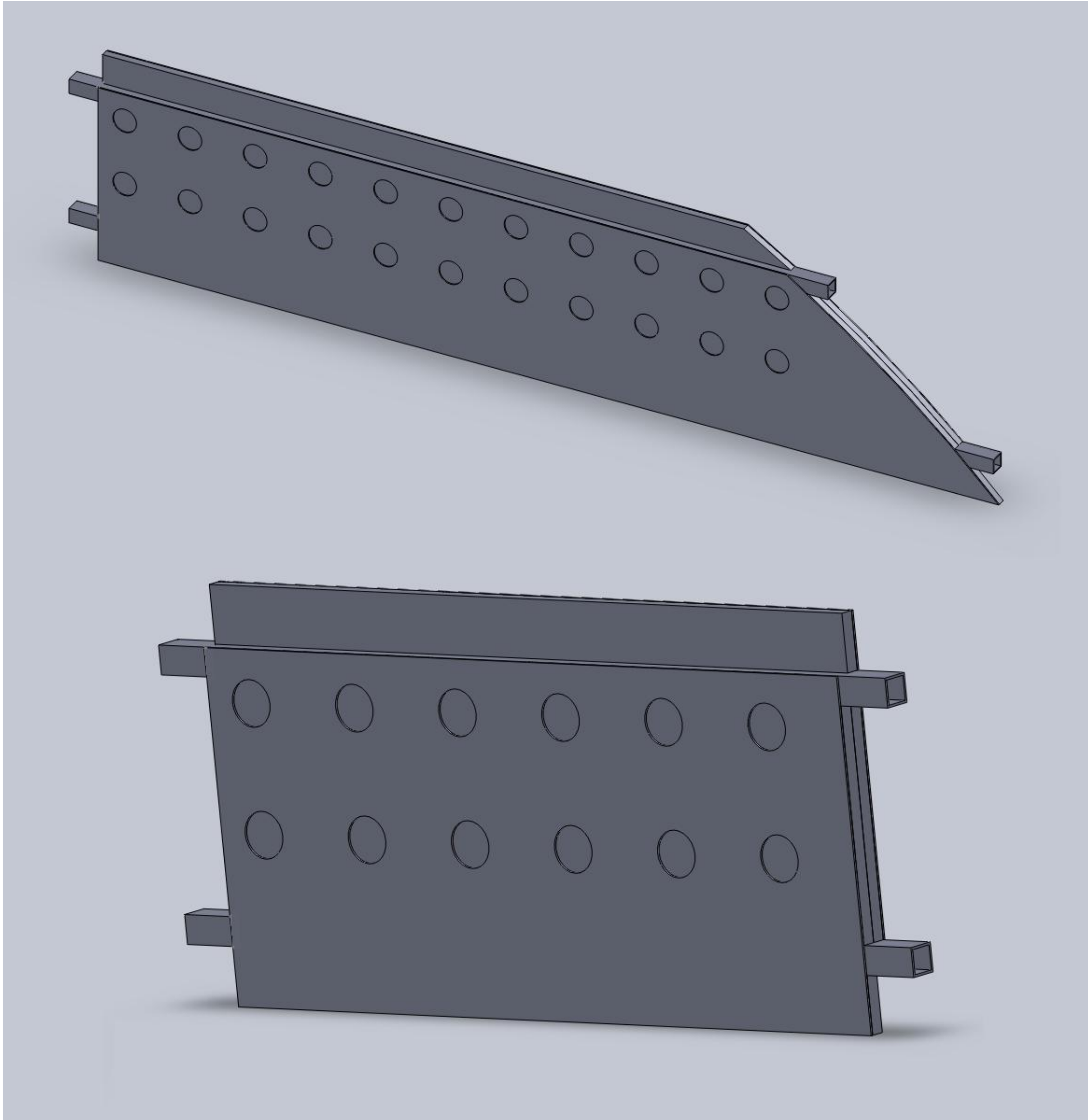

Figure 4: Examples of the Types of Panels Used

The panels used for constructing walls between each cabin and the corridor are all rectangular and of the same size; however the walls between each cabin must be arc-shaped on one side of the panel to account for the curvature of the outside wall of the habitat. On top of this, the length of these panels must also vary with the largest at the bottom of the wall and the smallest at the top, again to account for the curvature of the outer habitat wall. Finally, the doors are also composed of rectangular panels of equal size and a frame surrounding each door to maintain their shape.

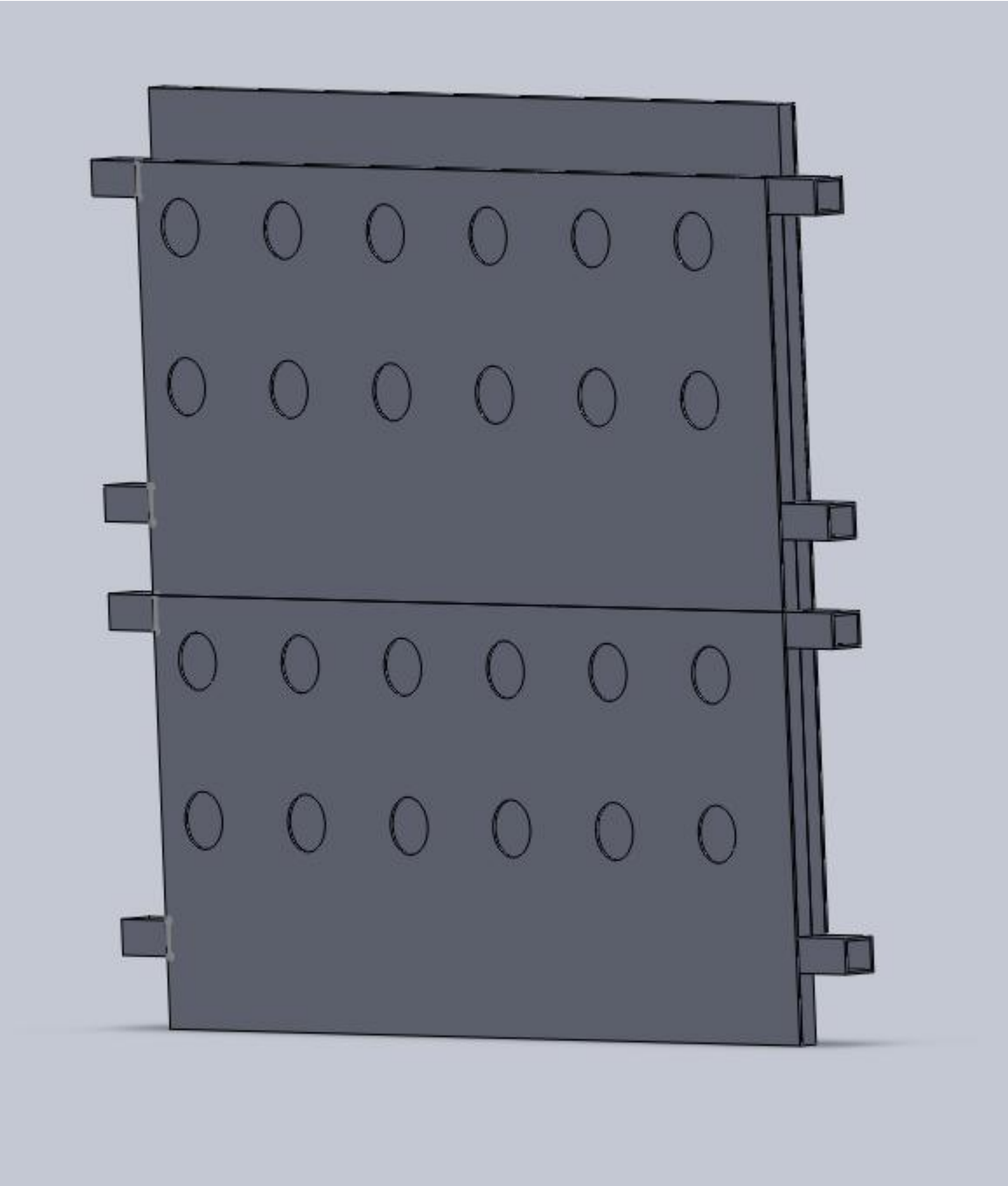

Figure 5: Example Showing Two Panels Overlapping

Rails

Three types of rails are required for this system; one for the walls between cabins, one for the walls between each cabin and the corridor, and a sliding rail for mounting each door.

The first type of rail is used to hold the panels in place. This is accomplished by having the panels sit on hooks built into the rails. There are 14 hooks on a rail that are used to fix 7 panels. The rails are mounted to the roof and floor.

To ensure low sound conduction between cabins, soft soundproofing material is applied between the rails and walls to reduce sound moving from one cabin to another through gaps. Each hook will also be rubberised to prevent any possibility of rattling caused by metal-on-metal contact, and to prevent slippage.

Steel has been chosen for constructing these rails due to its strength and ability to retain its shape. The reason for not using aluminium is that the yield strength of aluminium is relatively small compared with steel. It was judged that the hooks on an aluminium frame may not be strong enough to hold the panels over prolonged periods of usage.

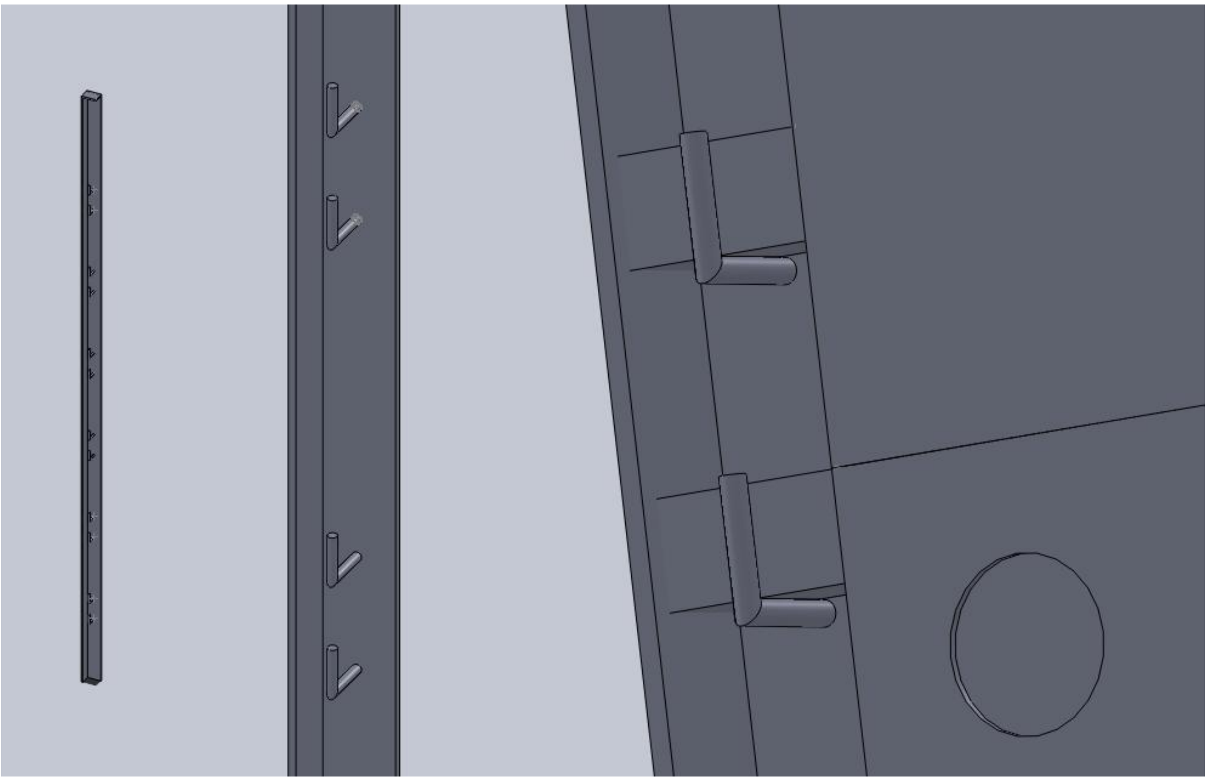

Figure 6: Rails with Close-up Views of Hooks

Doors

Each door consists of a steel frame with hooks onto which panels are mounted. One side of the door's frame can be detached so that the panels of the door can be installed or dismantled to ensure ease of storage and transportation.

The door shall be supported by two rails located in the floor and the roof. Upon these, the door will slide to enable access to and from each cabin. There will be a total of 9 sliding doors; one for each bedroom and an additional sliding door for the overall sleeping cabin area. This additional door will improve the sound proofing effect of the system.

This design for the doors, using the same panels as walls with a steel frame and the sliding mechanism, ensures similar ease of storage, transportation and sound proofing. The remainder of the system should also serve to reduce costs due to the same manufacturing processes and materials being necessary for all designs.

Mounting Points

A pair of mounting points is required for each single rail, one in the roof and another in the floor. The exact position of these mounting points depends on the design of the reconfigurable bedrooms. The recommended layout consists of three cabins on one side of the habitat and five on the other and is shown in Figure 13. The locations of mounting points are also shown in Figure 16. Since there will be spare inter-cabin walls when the total number of rooms is reduced, there are extra mounting points against existing walls so that some panels may be stored by constructing walls against existing walls.

4.3.3. Processes

Transportation

The system will require initial transportation to the habitat. Transportation will also be required if any components are stored off site or require replacing. While the panels are sufficiently small that they could be placed on the back of a utility vehicle, the rails may not be. It is possible a small truck will be required for transportation of the some of the system's components.

Installation

The installation of the system can be divided into three steps. The first is moving the panels, rails, and doorframes into the cabin. These will be brought into the habitat through the rear emergency exit, using the emergency ladder. The reason for not bringing them in through the lower deck is because the stairway from the lower deck to the upper deck is relatively confined. Based on the length of the rails and doorframes this may cause OH&S issues or possible damage to equipment on the lower level.

The second step in installation is attaching the rails to the desired pre-existing mounting points for the cabin configuration desired. These rails should be bolted to their mounting points to provide stability.

The final step is the installation of the panels. The panels for a wall are installed starting at the bottom because of the curved outer wall and interlocking between the panels. Each panel is lifted up and onto their respective hooks.

There are 16 pairs of rails with hooks and 9 pairs of sliding rails that need to be installed for the 8-bedroom configuration. Each wall requires installation of 7 panels. We anticipate installing a pair of rails and the corresponding 7 wall panels will take approximately 10 minutes. This gives an approximate total installation time of 250 minutes for the 25 wall segments. Additional assembly of the doors is estimated to be 18 minutes. Hence, the estimated time for initial installation of the system in the 8-cabin configuration will be about 268 minutes, or approximately 4.5 hours.

Reconfiguration

Reconfiguration takes place when the total number of bedrooms or the size of bedrooms needs to be changed. Reconfiguration of the bedroom layout is done by way of dismantling the existing walls and re-installing them in another area in the same manner as before.

The first step in uninstalling a wall is to remove the panels. This process begins with the top-most panel. It is unlocked using a sliding bolt and then lifted up from the hooks and detached from the rail. This is repeated for each panel. After removal of the panels, the rails are uninstalled by releasing them from the mounting points.

Combining two adjacent rooms into a double room is expected to be the most common activity completed by occupants regarding the system. For this reconfiguration, it is required that the wall between two rooms is uninstalled and reinstalled against another wall for storage. The time for uninstalling or installing a single wall is estimated to be 10 minutes. Hence it is estimated that combining two rooms into a larger room will take approximately 20 minutes.

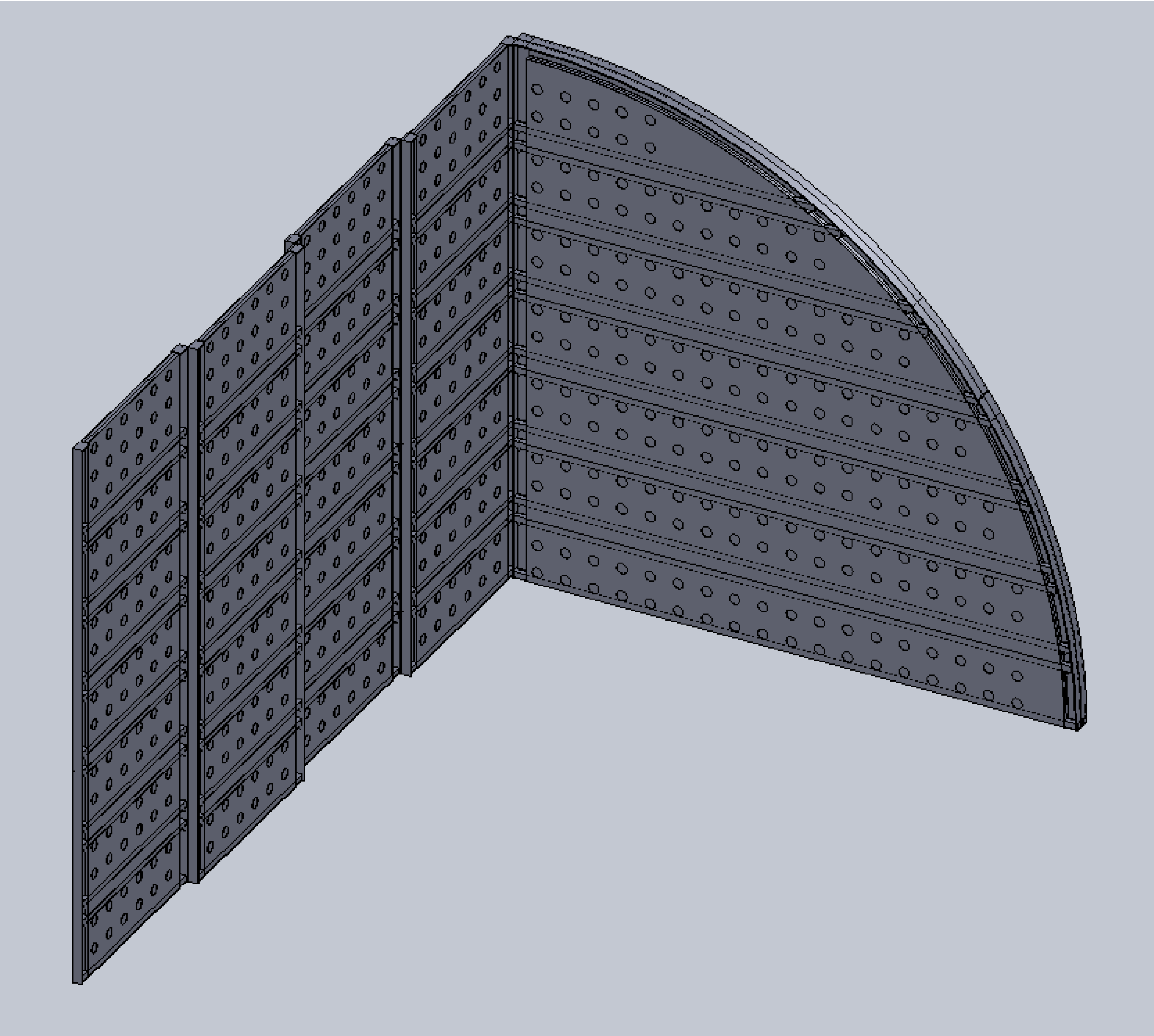

Figure 7: System Reconfigured for a Double Room (Note the Wall Separating Cabins is Now Twice as Thick)

Storage

There are multiple options for storage of spare panels and rails. The most suitable for the habitat is simply storing the spare walls against existing walls to avoid taking up additional storage space in the cargo-bay module. Upon reconfiguration to a smaller number of rooms, spare walls can be installed using mounting points that are close to existing walls making the walls effectively twice as thick, but effectively not using any additional storage space. An exception to this is the corridor wall that unfortunately cannot employ this method. This wall must be stored in the cargo-bay.

Maintenance

Spare panels of all types, cleaning chemicals, and simple maintenance tools should be kept on site for maintenance of the cabin walls and doors. It is expected that maintenance will only take place approximately every two weeks since the aluminium sheets, steel rails and steel door frames all have high strength and therefore can be considered to be reliable. The usual maintenance process involves cleaning the surface of the walls and the seam between interlocking panels, and checking that the rails are functioning correctly. It is possible that a panel may incur damage if impacted against; however in the case of this event only the affected panels need to be replaced rather than the whole wall. This is one of the advantages of a multiple panel design.

4.3.4. Preliminary Cost Estimate

The components of the Inter-Cabin Wall System include rails with hooks, sliding rails, steel frames for the doors, aluminium sheets, and soundproofing materials. The estimated quantities of materials required for these do not only include the quantity required for the design, but also surplus required for spare parts. The quantities of the materials needed are presented in Table 1 below.

Possible suppliers have been found for each of the materials given and the suppliers' websites are listed. Additional costs include the manufacturing cost of the panels. It is important to note that the total cost is a rough estimate and not a quote.

Table 1: Cost Breakdown for the Inter-Cabin Wall System

Name	Units	Quantity	Total Quantity	Manufacturer	Unit price	Total price
Rails with hook	**m**	Straight rails: 2.1*(9+2+15) = 54.6 Curved rails: 3.3*5+2.5*3 = 24 Spare rails: 2.1*2+3.3+2.5 = 10	54.6+24+10= 88.6	http://www.metalsupermarkets.com/MSC-Home.aspx	$12	$1063.20
Sliding rails	**m**	Four-bedroom side: 1.8*2*4=14.4 Five-bedroom side: 1*2*5=10 Spare rails:1.8+1=2.8	14.4+10+2.8 =27.2	http://www.metalsupermarkets.com/MSC-Home.aspx	$14	$380.80
Manufacture cost for panels	**Sq.m**	Panels between bedrooms and corridor: 2.1*(6.75+6.425)=27.67 Panels between bedrooms: 3.46*5+1.95*3=23.15 Spare panels: 1.35+2.1+3.46+1.95=8.86	27.6675+23.15+8.86 =59.68	http://www.alcoa.com/global/en/home.asp	$11.5	$686.30
Frame of door	**m**	Frames of door: 18*2.1+2*2+2*2+1*2=47.8 Spare frames: 2.1*4+0.4*2+0.67*2=1	47.8+10.54 =58.34	http://www.cecodoor.com/	$18	$1050.12

		0.54				
Aluminium sheet (1mm thick)	**Sq.m**	Frontage of panels: 101.64 Side of panels: 10.164 Spare sheets: 8.86*2=17.72	101.64+10.164+17.72 =129.524	http://www.alcoa.com/global/en/home.asp	$17.5	$2266.67
Sounding proof material	**Sq.m**	In all panels: 101.64 Spare: 8.86	101.64+8.86 =110.5	http://www.soundprooffoam.com/quiet-barrier.html	$15	$1657.5
Total						**$7104.59**

4.4. Combined Bed/Desk System

4.4.1. Chosen Design

The chosen combined bed-desk design is a modified version of the basic *CABRIO IN* model produced by *CLEI Furniture* as seen in Figure 8. Modifications include the removal of one of the lateral sides to reduce weight and maximize comfort, the original frame structure is replaced by a simpler design to improve stability and manufacturability, and the upright storage of the bed is modified to be stored at an angle to accommodate the curved ceiling of the habitat. With these modifications, the design is deemed to meet the main fit-out requirements of the sleeping cabins. The system can be manufactured using raw materials by volunteer labourers.

Figure 8: CABRIO IN Bed/Desk System

Although buying the commercially available system from *CLEI Furniture* reduces the complexity of construction and guarantees good workmanship, custom manufacture of the system should prove more cost effective. The existing product has been identified as luxury furniture with costly Melamine finishes providing visual appeal. This finish can be replaced with a cheaper option such as clear lacquer that should be relatively inexpensive whilst still retaining the aesthetically pleasing appearance.

4.4.2. Components

The combined bed-desk system consists of 3 vital components. The mattress is the most important in determining the size of the bed as it must be custom made in order to fit within the limited cabin size. The bed is secondary as the mattress determines the size of the bed and the bed can be constructed easily with raw materials by volunteers because of the simple design. The least consideration is given to the desk. The desk requires the least precise workmanship and skill, and is subject to fewer technical specifications.

Mattress

The final size of the bed is dependent on the size of the mattress. After consideration the small single size used in the United Kingdom (UK) was selected. This mattress is 1800mm in length, 750mm in width, and 180mm in height. These dimensions were the optimal choice for the cabins to maximize the living space. Even though this size of mattress is readily available in the UK, importing from the UK will attract a significant cost. Therefore options for manufacturing this mattress locally were researched. As a result, a company within Canberra, called Makin' Mattresses Pty Ltd, was selected. Makin' Mattresses specialise in the custom design and fabrication of mattresses. The manufacturer has since confirmed that a mattress can be manufactured according to any customer dimensions.

The custom design has heavy-duty springs throughout the mattress that are to be cushioned by layers of 10mm high-density polyurethane foam. The foam is also non-allergenic and can be used by crew members with latex-sensitivity. Extra heavy-duty hourglass edge supports shall be installed for maximising sleep surface and durability. The mattress shall be covered with 18mm quilted fire retardant fabric which meets the Australian Standards for fire safety AS1530.3/1999 & AS2755.2/1995. The mattress shall also be double sided, so that its life can be extended by rotating it regularly.

Bed

The bed base was designed based on the dimensions of the mattress. The bed base shall be 1840mm in length and 790mm in width and 15mm in thickness. The height of the top of the bed base from the floor shall be 200mm.

The overall structural frame is to be made of reinforced 20mm square hollow steel and painted with epoxy powder for corrosion resistance. Although in many cases, aluminium may be a suitable substitute for steel, the decreased weight of the aluminium detracts from the usability of this system. Because the system must be stable when a person is sleeping on the outer edge of the bed, it is important that the system has sufficient weight to balance the moment created by the person's weight. The bed base shall also be made of 20mm square steel, with multiple layers of bent beech wood. Belts made of nylon fibres with fasteners are to be used to secure the mattress in place when it is stowed. The opening mechanism will be supported by gas springs (slow dampening type) for smooth release of the mattress. The legs of the structure shall be fitted with castors each with a locking mechanism to enable switching between mobile and stable configurations. The bed shall be supported by two flat steel bars protruding from the side frames and a lengthwise square steel bar. When the bed is being used, the bed base rests on these supports.

Desk

The desk shall be 1840mm in length and 500mm in width. When in use, the height of the desk from the floor will be 700mm. The height of the desk when lifted for stowage shall be 1100mm. The distance between bed base and desk in its stowed configuration shall be 900mm (without the mattress). The desk shall be made of beech wood with clear lacquer finish. Steel bars are to be used to connect the desk with the bed.

Figure 9: Existing Product for the Proposed Combined Bed/Desk System

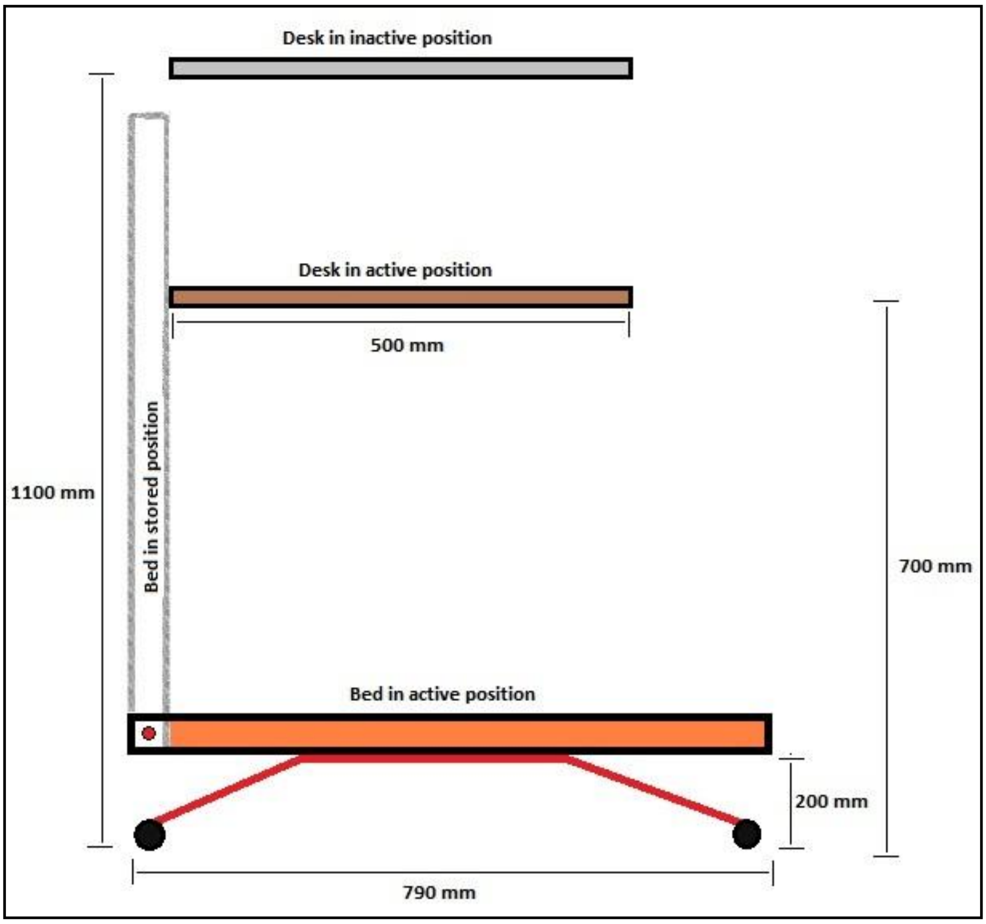

Figure 10: Dimensions of the Combined Bed/Desk System

4.4.3. Processes

Installation

Due to the size of the system, it cannot be fully pre-assembled outside the module and then moved in. Therefore it is necessary to assemble some individual pieces once they are moved into the cabin.

The main components are the frame, bed slats, mattress, and desk. To form the main frame of the system, pre-assembled sidebars can be manoeuvred into the cabin and then the crossbars can be attached and secured with nut and bolts. The desk shall be attached with the supporting steel bars as well as moving joints with gas springs beforehand. A similar process will be applied to the bed as well. The rotating joints with gas spring are attached to the bed base and the bent beech wood slats are attached to the base. Once all these subsystems are pre-assembled these are brought into the habitat, after which the system as a whole can be assembled with nuts and bolts with the aid of a wrench or spanner.

First, the crossbars are attached to the side frames completing the whole main frame. Then the bed base is attached to the main frame using the pre-assembled gas springs. The mattress is then secured to the bed base using the nylon fibres and fasteners. Finally the bed is moved to the storage position and the desk can be installed. Once the system has been completed, it is important to check that all nuts and bolts are securely fastened before use.

Transportation

The system includes four castor wheels to permit it to be easily moved throughout the habitat when necessary. These castors are made of nylon. They include a revolute bearing, a swivel plate for attachment, and brake.

Maintenance

The system has a minimal number of moving parts. Thus the maintenance needs of the system are significantly reduced. The moving parts require lubrication on a monthly basis. The frame is corrosion resistant. Adequate care should be taken to avoid the use of strong acids as cleaning-agents as this will remove the anti-corrosive epoxy powder coating. Only mild cleaning agents will be suitable for cleaning the frame and desk.

Figure 11: Example of Castor Wheels Used in the Bed/Desk System

As seen in Figure 11, when the brake is not engaged, the wheels are free to rotate, allowing the system to be moved freely around the cabin. When the brake is engaged the system's mobility is restricted and it becomes stable for use.

When the system needs to be transported out of the cabin, the desk should be removed. This increases the manoeuvrability of the system. Though the constructed system is not heavy, its physical bulk will necessitate the use of trucks for transportation unless it is disassembled to parts.

4.4.4. Specifications

There will be some requirements that MARS-OZ will have to meet to ensure safe and effective usage of the system.

The maximum weight supported by the bed's slats is 120 kg. When any load greater than this is applied, the system risks either toppling over or experiencing structural failure of the metal frame.

The maximum weight the desk can support is 20 kg. It is extremely unsafe to apply a greater load than this as the desk is situated directly above the bed in which someone may be sleeping. Failure to follow safety limits may also result in structural failure of either the table itself or the bearings.

The maximum weight supported by each castor wheels is 30kg. Spread over four wheels this gives a maximum load of 120kg. It is important to note that this maximum weight is when the castor wheels are in stable locked position. When the locks are released, the maximum weight the bearings of each castor wheel can handle is 20kg. Therefore it is advised that the castor wheels are to be used to move the system when there is no load on the bed or desk.

4.4.5. Preliminary Cost Estimate

Since the bed-desk system will be locally manufactured by volunteers, a cost analysis has been conducted to estimate the approximate cost of 8 units of these systems.

Table 2: Cost estimate of combined bed-desk system

Part	Units	Quantity	Total Quantity	Manufacturer	Unit Price	Total Price
Small single mattress			8	http://www.makinmattresses.com.au/	$400	$3,200
Beech wood	Square metre	2.5 per unit	20	http://www.woodworkerssource.com/PRO-bee44-p-beech.html	$100	$2,000
Gas springs		4 per unit	32	http://www.nextag.com/gas-spring/compare-html	$50	$1,600
20mm square hollow steel	Metre	20 metres per unit	160	http://www.parkersteel.com/Product/0013854/Bright+Steel+Square/20mm+SQUARE+080A15+BLUE	$10	$1,600
Miscellaneous*						$1,600
Total						**$10,000**

*Miscellaneous items include castor wheels, screws, bolts and leeway for replacement materials.

4.5. Overall Sleeping Cabin Layout

4.5.1. Overall Cabin Plan

The layout of the bedroom system was based on three requirements; there must be eight reconfigurable bedrooms, all rooms must be approximately the same size and all rooms must be fitted with the specified equipment required by MARS-OZ (document MS-1). To achieve this, all bedrooms are approximately 3.050m^2, with bedrooms 1 through 3 having dimensions of 2.100m by 1.450m and bedrooms 4 through 8 having dimensions of 2.259m by 1.350m, as can be seen in Figure 13. This room sizing leaves a corridor with a width of 0.713m. While this is quite small, it should be noted that it is sufficient for human movement around the habitat and for carrying baggage to and from the cabins. 0.713m will not be sufficient for the transport of large items to and from the cabins; however, this is acceptable as the transport of large items into the habitat is expected to occur before the inter-cabin walls are constructed, or alternatively the walls can be deconstructed to allow for this.

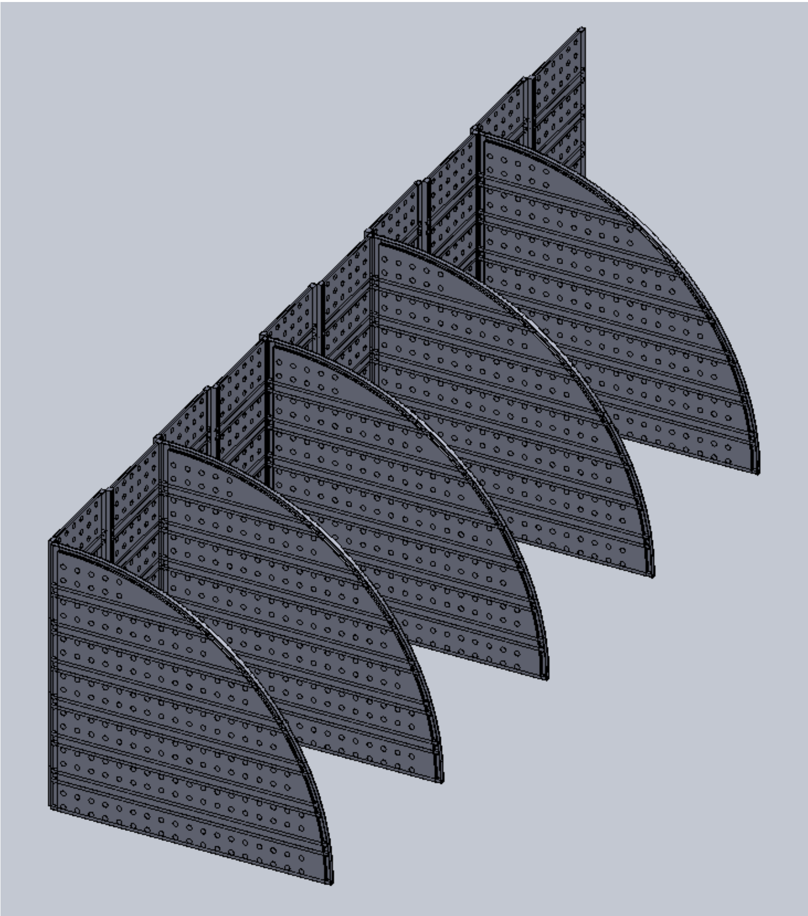

Figure 12: View of a Number of Assembled Sleeping Cabins

Some aspects have been changed from the original design, seen in MARS-OZ document MS-3, for the upper deck layout. The store and linen cupboard were moved in front of the living area, towards the nose of the habitat, as may be seen in Figure 13. This has made it possible for a full transformation from 8 bedrooms to one large room. It may also be advantageous to have the store room closer to the kitchen. In addition, the living area was also made considerably smaller due to the introduction of an additional bedroom (bedroom 8) which was necessary to meet the requirements of MARS-OZ. It is suggested that these bedrooms should be filled sequentially (1 through to 8) as this retains the greatest amount of living space until all bedrooms are filled.

The inter-cabin and corridor walls of the habitat have also been taken into account with a thickness of each wall of 50mm added to the layout in Figure 13. The walls have mounting points in the floor and roof in the as shown in Figure 16, which are discussed section 4.5.4.

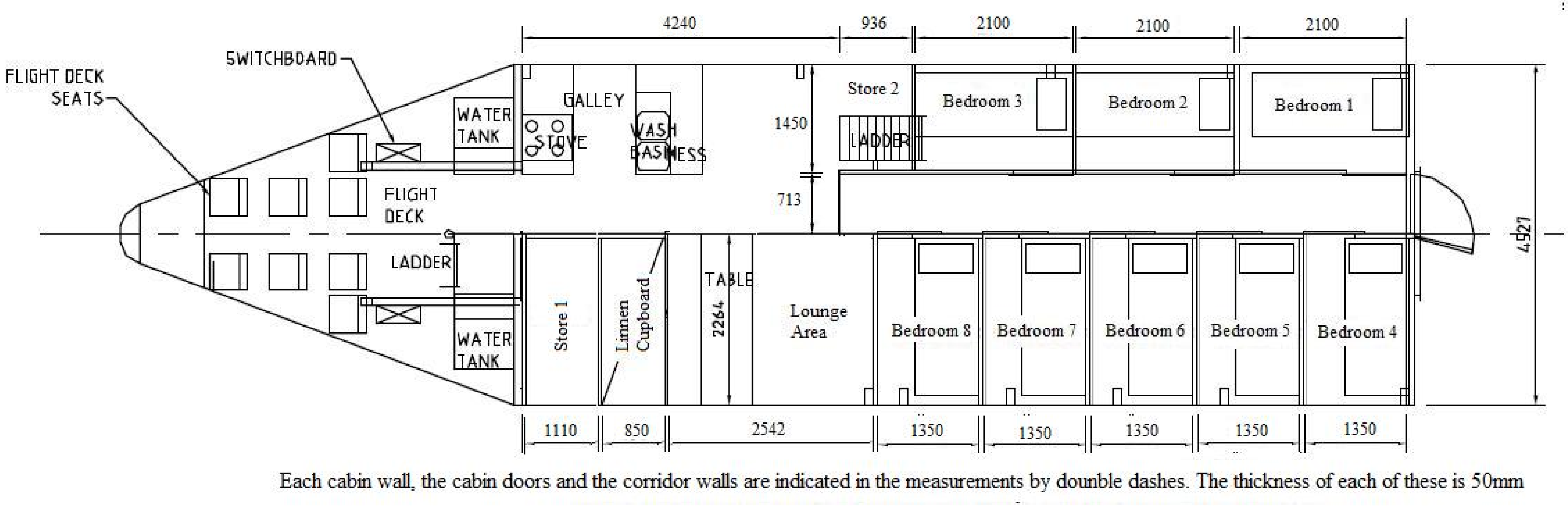

Figure 13: The proposed upper deck and bedroom layout for the MARS-OZ habitat. All measurements shown are in millimetres (mm).

4.5.2. Cabin Living and Storage Space

Each bedroom is fitted with a single bed taking up 1.4536m^2 of space when in use, with dimensions of 1.84m by 0.79m. This leaves approximately 1.6m^2 (3.05m^2 less 1.45m^2) of floor space in each room. For bedrooms 1 through 3 this will leave 0.26m by 0.79m or 0.2054m^2 at the end of each bed, assuming that all walls are in place, and 0.66m by 2.1 or 1.386m^2 to the side of the bed with the door. For bedrooms 4 through 8 this will leave 0.308m by 0.79m or 0.2433m^2 between the foot of each bed and the external wall and 0.56m by 2.264m or 1.2678m^2 to the side of the bed, assuming that the walls are all in place.

It is realised that crewmembers will need to utilise this remaining floor space in the cabins to store their clothes, as well as a small amount of other personal belongings, for example toiletries. It is suggested that crewmembers' suitcases be stored in one of the following areas; the linen cupboard, either of the stores, or in the storage space in the cargo-bay. This will help to avoid OH&S issues caused by suitcases being stored on the floor. It is suggested that each crewmember’s clothes and small belongings be stored in racks which will be hung from the ceiling, as seen in Figure 14. These racks are soft and therefore should reduce OH&S issues, whilst being very lightweight and providing enough rigidity and space to store the crew member’s clothes and other light belongings. These racks can have up to 8 compartments, but it is suggested that four compartments would probably suffice; one compartment for undergarments, one for shirts, one compartment for trousers/skirts and one for jumpers, with shoes to be stored on the floor or in remaining compartments if required.

For the occupant’s laptops, books and other equipment, it is suggested that these be stored on the desk part of the bed/desk system during the day and in the space underneath the bed during the night. Stationery (pens and pencils, etc) should be stored in pencil cases when not in use to eliminate clutter, promote cleanliness and reduce OH&S issues.

Figure 14: Hanging shoe racks which crew members could store their clothes and small personal belongings in (Image from Dansky 2008).

4.5.3. Overall Storage

The general storage on the upper deck will be a 1.110m by 2.264m store room, located behind the flight deck and adjacent to the galley. Another storeroom which is predicted to be approximately 0.936m by 0.725m but can be modified by MARS-OZ, is located next to the stairs and behind bedroom 3. A 0.850m by 2.264m linen cupboard is situated between the first store and the living room. This gives a total floor area of approximately 5.12m^2 for general storage space, which will be increased by the addition of shelves inside of the stores and the linen cupboard. This will however be constrained by the chosen shelf heights and the curvature of the outer walls of the habitat.

In addition to the storage space outlined, there is also a considerable amount of space not yet utilised located between the galley and the stairs which could also be used as a third store room. Finally, in the case of an emergency, the living area may also be able to provide additional general storage space.

4.5.4. Specifications

For the inter cabin wall system to be incorporated into the MARS-OZ habitat design, the MARS-OZ habitat will need to be modified to include the floor mounting points for the walls, which can be seen in Figure 16. In this figure, the mounting points for the doors to the cabins and the corridor walls are highlighted with red squares, with each mounting point having dimensions of 25mm by 50mm. The mounting points for the cabin walls are highlighted by blue squares and also have the same dimensions as the red mounting points, but are perpendicular in position to the red points. Where the blue mounting points appear on the lines of the walls, this is the standard position which will be utilised when all the bedrooms are being used. The other additional blue mounting points, which will be placed 10mm to the side of the standard mounting points, will be utilised in the case that bedrooms are expanded, such that the one wall will be moved against another wall for storage, as may be seen in Figure 15.

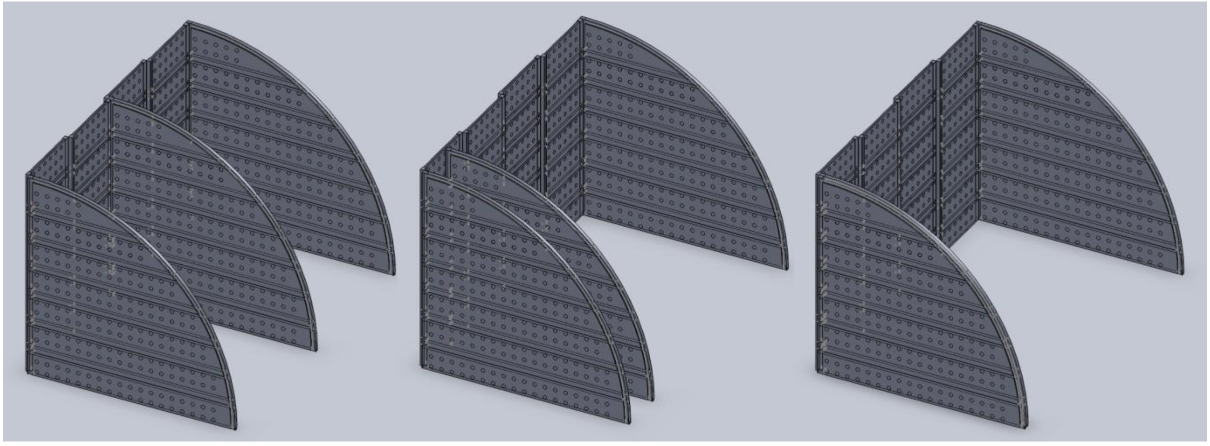

Figure 15: Conversion from two single rooms to a double room

This method of storage means that if the rooms are expanded, the crewmembers will not have to move the panels of the walls downstairs to be stored in the garage area. This should reduce OH&S issues associated with moving the panels up and down stairs and save time. If two walls are stored in bedrooms 1, 2 or 3 this would reduce the length of the bedroom to 1.98m, which remains sufficient to allow the incorporation of the bed/desk (1.84m long) and would provide a residual total room floor area of 2.871m^2. If two walls are stored in bedrooms 4, 5, 6, 7 or 8 this will reduce the width of the bedroom to 1.230m which remains sufficient to allow the incorporation of the bed/desk (0.79m wide) and would provide a residual total room floor area of approximately 2.785m^2.

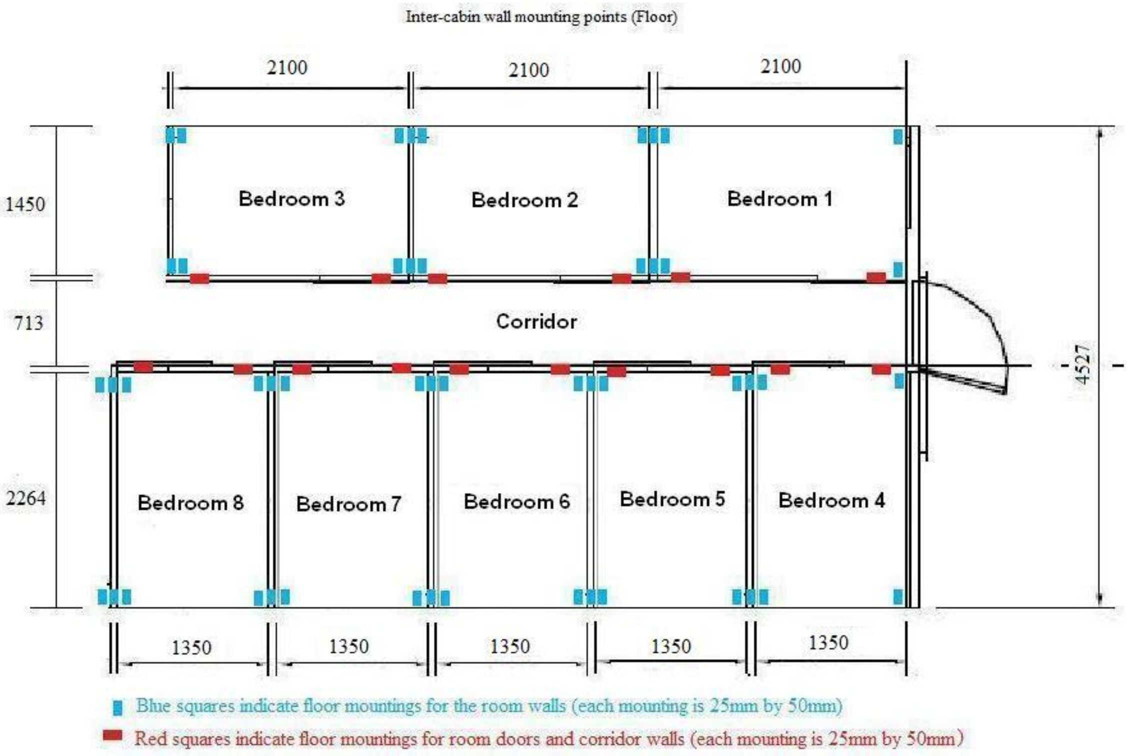

Figure 16: A plan view of the bedrooms and corridor displaying the mounting points for the inter-cabin walls. NOTE: All measurements are in millimetres (mm).

4.5.5. Room Layout

As specified by MARS-OZ document MS-1, each cabin must be fitted with a main light, a reading light, a LAN port, a power supply, appropriate stowage, a fire detector, a fire extinguisher, and a porthole, in addition to the bed/desk system. The proposed layout for bedrooms 1, 2 and 3, which have dimensions of 1.35m by 2.1m, can be seen in Figure 17 and the proposed layout for bedrooms 4, 5, 6, 7 and 8, which have dimensions of 2.264m by 1.35m, can be seen in Figure 18. All of the appliances listed above, as specified by MARS-OZ, have been included in the bedroom layout plans of both sets of bedrooms and their positions in the room have been fully dimensioned. The dimensions will not be discussed here as these are visible in Figure 17 and Figure 18. The design considerations behind the choice of these dimensions will however be briefly outlined.

It was deemed that no fixture could be installed any closer than 600mm from any of the reconfigurable walls, as this would interfere with the wall storage procedure. An additional constraint was put on the fixtures that they must not be built into the reconfigurable walls and therefore must be installed in the roof, outer wall or the floor. The main light of each room was put as close to the centre of the room as possible and close to the highest point, in each room to provide the best light due to the curvature of the outer walls.

The fire detector was placed near the doors of the cabins, as this way they would be able to cover an area that not only included the room but also some corridor space outside the room. The small fire extinguishers, which are 84mm in diameter by 351mm in length (Fire EMT 2011), were placed in spaces that would be easily accessible, but cause minimal interference to daily routines and would save space.

The portholes were placed in the centre of the outer wall for symmetry and ease of access. The LAN port and dual general power outlet (GPO) were placed next to each other and then designated a position next to the bed/desk system for easy access and use.

The hanging clothes racks, which were estimated to be 500mm by 500mm, were placed in positions were it was deemed the roof would be high enough to provide sufficient space to hang them, while interfering as little as possible with movement in the cabin.

Finally, a reading light was positioned over the bed/desk. It is assumed that this light may have a swivel function similar to reading lights in commercial planes or that it will have a ‘gooseneck’ that will allow it to be conveniently repositioned.

Finally, it should be noted in Figure 17 and Figure 18 that the bed and the clothes rack do not adhere to the constraint given that no fixture could be installed any closer than 600mm from any of the reconfigurable walls, as this would interfere with the wall storage procedure. This is deemed satisfactory as neither the clothes racks nor the bed/desks are fixed and can both be moved in the event that the wall storage procedure is utilised.

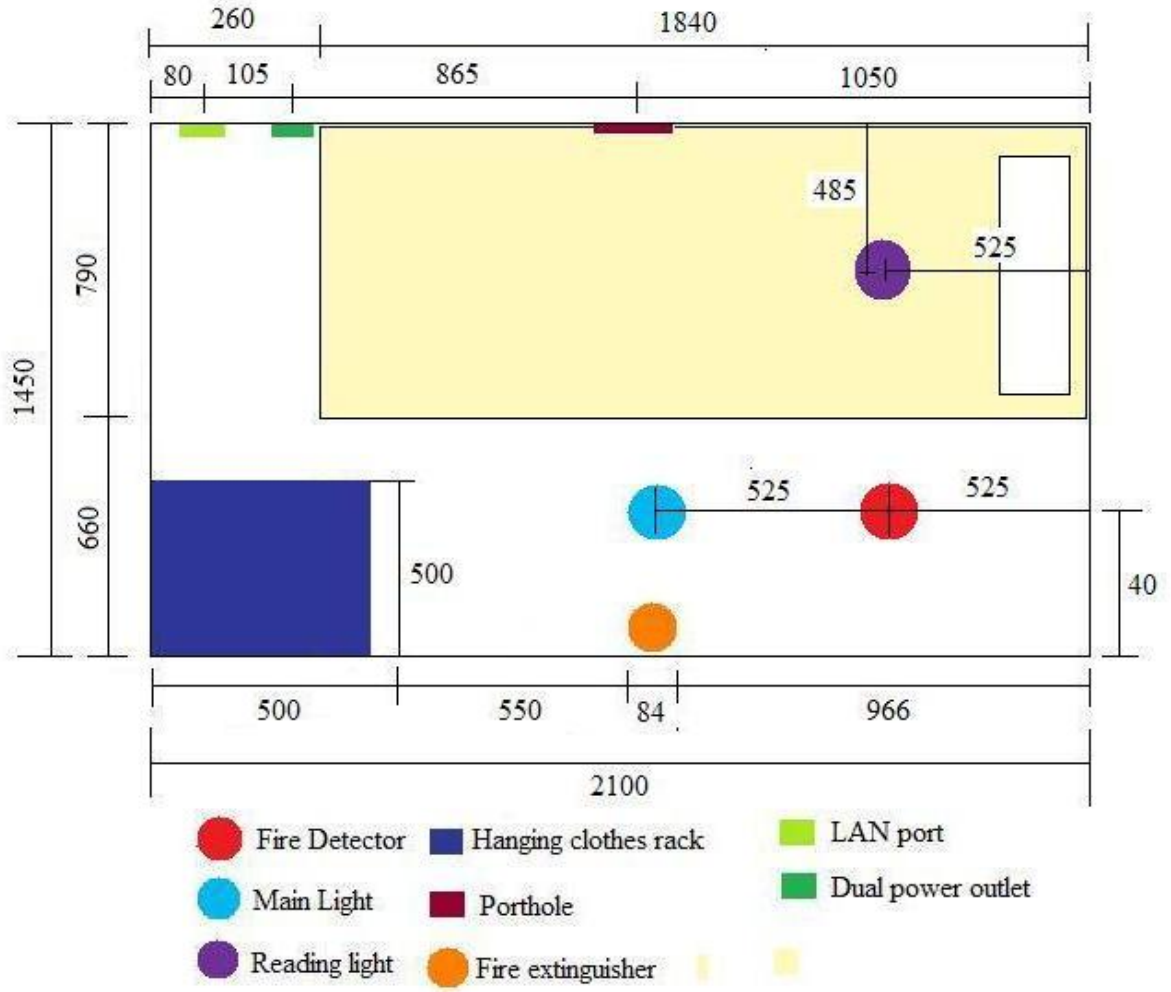

Figure 17: Fully dimensioned bedroom layout for bedrooms 1, 2 and 3. The curved outer wall is located at the top of the figure and the door to the cabin is located at the bottom of the figure. All measurements are in millimetres (mm).

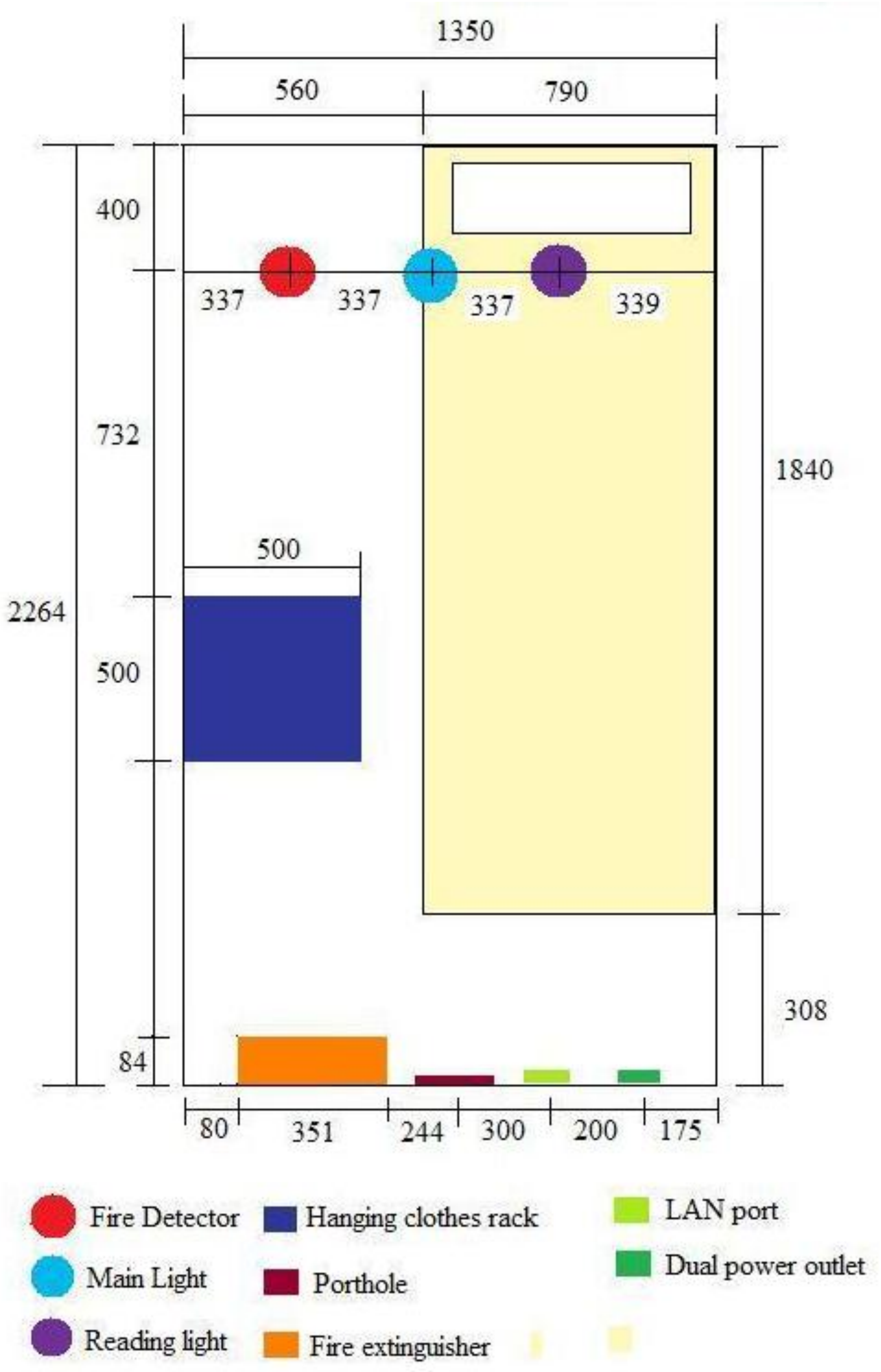

Figure 18: Fully dimensioned bedroom layout for bedrooms 4, 5, 6, 7 and 8. The cabin door is located at the top of the figure and the curved outer wall is located at the bottom of the figure. All measurements are in millimetres (mm).

4.5.6. Brief Layout Cost summary

The cost of the bed/desk system has already been discussed in Section 4.3.4. In addition to this there will be further costs associated with the fire detector for each room, as well as a fire detector and a fire alarm speaker for the corridor, a fire extinguisher for each room, and the clothes rack. It is also recommended that a manual call point for the fire alarm is fitted to the emergency door at the back of the habitat. The lights will not be included in this section as the lighting layout design is not within the scope of this project.

As described in Section 5.2.2 each fire detector, with base, will cost $115 and will be linked to the fire alarm system in a manner shown in Figure 23. The fire alarm speaker for the corridor will cost $20 and the manual call point for the emergency door will cost $30. Additionally, each small fire extinguisher will cost approximately $33 (Fire EMT 2011) and each clothes rack will cost approximately $20 each.

- 9 x fire detectors = $1035
- 1 x fire alarm speaker = $20
- 1 x manual call point = $30
- 8 x small fire extinguishers = $264
- 8 x clothes racks = $160

This leads to a total cost of $1509 for the bedroom and corridor fit-out excluding the bed/desk system and inter-cabin wall system. Note that this is only a preliminary cost estimate and not a quote.

4.6. Summary

The Internal Architecture sub-group has produced two system designs for the sleeping cabins, including plans for implementing these designs and an overall configuration for the sleeping cabin system as a whole.

Mars Society Australia has specified that they would like the sleeping cabin area to be reconfigurable to accommodate varying crew sizes. To this end, the team has produced a wall system capable of being erected and dismantled quickly, reconfigured, stored and transported with ease. This design solution is a system of separate interlocking panels, which install onto removable rails mounted vertically from the floor to the ceiling.

Mars Society Australia have also specified that any sleeping cabin design should incorporate human factors, taking into account the need for crew member privacy given the confined living spaces they will inhabit for extended periods of time. To meet these requirements it was decided that at a minimum, each cabin must incorporate a bed, a desk, and some personal storage. A combined bed/desk system was developed based on existing commercial designs. Due to the small spaces involved and curved ceiling a number of modifications to any existing design would need to have been made for such a product to be adequate. For this reason it is suggested that a custom system be manufactured to more adequately meet the needs of MARS-OZ. Plans for such a system are presented in section 4.4 above.

In order to accommodate 8 crewmembers some modifications to the MARS-OZ habitat plan published in MS-3 in 2003 were required. This involved relocating the proposed storage areas and demarcating an extra sleeping cabin. It is also suggested that foldable hanging compartments (commonly hung from rails in cupboards in households) be provided in each sleeping cabin. These are useful because they fold up to a very small size when not in use, and can be installed in an otherwise unused space.

5. Waste Management and Water Recycling Systems

5.1. Introduction

The following section outlines the proposed design solutions for a Waste Management System (WMS) and a Water Recycling System (WRS) for the MARS-OZ habitat. This document presents a detailed overview of the conceptual designs for both the WMS and the WRS.

The design solution chosen for the WMS consists of two distinct and physically isolated subsystems. The first of these is for the processing of general wastes by incineration. The second of these is for the processing of wet sewage waste by means of an incinerating toilet unit. The design has utilised off-the-shelf technical solutions to accomplish the central functions required of these subsystems, primarily destruction by the incinerating units.

The general waste incinerator is the MediBurn-20 Incinerator® Unit manufactured in the United States by Elastec Inc. (USA). The INCINOLET Electric Incinerating Toilet® by Research Products/Blankenship Inc. (USA) has been selected to perform sewage incineration. The functional performance of the units being taken as documented, the system design hence focuses on the necessary system integration considerations of these incineration units into the overall MARS-OZ mission system.

The design solution for the WRS was approached from the perspective of meeting two key functional requirements. These were the ability to reprocess wastewater and the ability to store water. Due to the safety aspects surrounding the human consumption of water, off-the-shelf technical solutions with proven safety standards were mandated. The Villager A1 Filtration and Disinfection system manufactured by Aqua Sun International Inc. (USA) was selected to fulfil the role of processing functionality. A parallel design process indentified the required storage vessels, pumps, and pipes to fulfil the role of water distribution and storage. It is currently proposed that the storage system should be custom manufactured. This achieves a lower cost storage system solution and affords a design that is better suited to the unique spatial limitations of the habitat.

5.1.1. Scope

The physical means and operational protocols by which waste is to be processed have been developed. This addresses the necessary waste collection, storage, and processing functionality. The use of this system shall be limited to those waste types identified within the current design project scope. The system integration functions that enable the systems to accomplish these tasks are within the project scope. These systems may not directly relate to waste processing, but are instead required for safe and effective unit operation.

Table 3: Delineation between waste types according to project scope.

Waste Streams Considered	Waste Streams NOT Considered
Organic matter (food and plant matter)	Metallic wastes
Human waste (sewage)& Medical waste	Hazardous research/scientific waste
Plastics	Radiological

The system design for waste destruction is generally only limited to relatively dry waste, but also includes wet waste types such as human and medical waste. Wet waste (putrescible types) is significantly more difficult to handle and process. These require additional energy to process and can putrefy if not promptly processed. The design focuses on how these wastes can be safely rendered to inert disposable products.

The strategy used by Martian Designs has been to approach the design scope through two subsystems, each handling either wet or dry waste. The first of these subsystems is the General Waste Management System (GWMS) for the destruction of general (dry) refuse. The second of these is the Human Waste Management System (HWMS) for the destruction of human waste (sewage). High moisture non-human waste is not considered. However, the particular general waste incineration system considered should be capable of processing these waste types with added energy expenditure.

5.2. Waste Management System Detailed Design

5.2.1. Design Choices

The pre-conceptual design identified three candidate technical solutions for waste management. These were supercritical waste oxidation and gasification, and incineration. Of these options, incineration as a tried and tested technique for waste destruction was chosen. As incineration generally deals with mainly dry waste (low moisture), a hybrid system of incineration was employed. The system manages and processes general waste and human (sewage) waste separately.

The hybrid incineration waste system consists of two physically isolated subsystems. The general waste disposal system is framed about the Mediburn-20 Incinerator. This incineration system is to be located in the cargo-bay module. The INCINOLET Electric Incinerating Toilet® provides the means of human waste disposal. This is located in the bathroom within the habitat section, in place of a traditional flush-toilet.

The Mediburn-20 product data sheet was obtained from Elastec Inc. The system was designed to act as a portable incineration unit for small remote medical facilities. The incinerator consists of two temperature controlled incineration chambers, fired by diesel burners to achieve a 1000°C burn. This achieves the complete disinfection of all contaminated materials. The primary chamber can accommodate 0.22 cubic meters of infectious and pathological waste. The incinerator can process 20kg/h of waste and uses 0.5 to 0.9 L of diesel per kilogram depending on the moisture content of the waste. Unit control can be exerted automatically with preset cycles for start-up or shutdown. The system has been used by the US Military for mobile waste incineration requirements, and has been used in the US where it meets US EPA environmental standards.

INCINOLET toilets are the ideal replacement for flush toilets. These have both similar physical dimensions and mass, which means no alterations are required to the internal layout of the bathroom or the structural support system incorporating the INCINOLET. The INCINOLET also relieves the requirement for waste conduit services by performing the incineration within the unit itself. To perform the incineration the INCINOLET requires 3.6kW of electrical power, supplied at 240 V AC on a 20-amp circuit.

Figure 19: Incineration Equipment – Mediburn-20 Incinerator (left) and INCINOLET Toilet (right).

5.2.2. General Waste Management Subsystems

The following subsections identify the key subsystems for the general waste management system. These introduce the system equipment and the integration of such items. Individual equipment items including a description and details are provided in Section 15: Appendix III: Waste Incineration System Components. These consist of the waste collection and handling subsystem, the in-floor storage subsystem, the ventilation and fire safety subsystems, workplace integration subsystem and the incinerator subsystems.

Collection and Handling Subsystem

Our concept for waste collection meets the key requirements for safe and efficient waste handling within the habitat. Having identified the likely waste generation locations (see Figure 20) within the habitat, an appropriately coloured bin was allocated. The hands-free trash receptacle (20L) system by SULO waste management (SensaTouch™) is envisaged. Source separation requirement is achieved using the following bin colour-coding scheme:

- Green bins are allocated for food scraps and plant matter
- Grey bins are allocated for generic refuse for incineration (paper, plastic)
- Red bins are allocated for the collection of non-incinerable waste
- Yellow bins are allocated for medical and hygienic waste

The trash receptacle colour-coding system is correspondingly continued in the colour-coding system of bin-liner. A tear-resistant HDPE medical-waste bag available in various colours should be considered. This reduces the risk of waste spillage within the habitat.

Waste is transferred from the source (the various waste bin locations) to the cargo bay using a sealable heavy-duty 50L container. This container should fit compactly within storage, and provides buffering waste storage capability. Relatively modest waste generation makes a larger wheeled system unwarranted, and makes direct handling the most viable proposition. A system of protective clothing is devised to provide the necessary mechanical, thermal, and chemical protection.

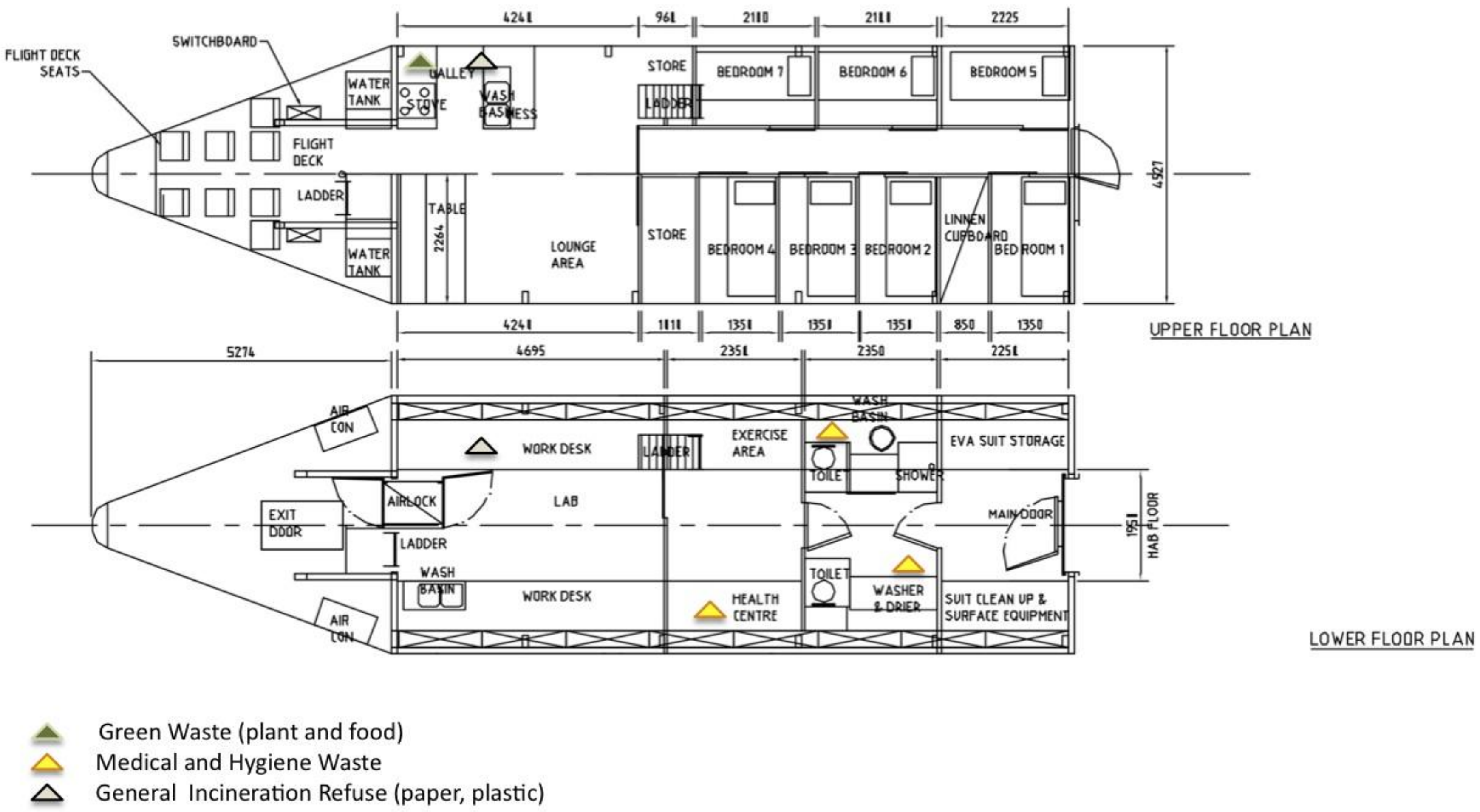

Figure 20: Waste Generation Points within the Habitat

In-Floor Storage Subsystem

The design envisages that storage shall be located within the floor-space of the cargo bay. To both fully restrain items within the space whilst maximising the useful space, the segment belying the floor space is split into one large compartment and two equally sized smaller compartments. The cross-sectional dimensions of these compartments are shown below in Figure 21. For current purposes the design includes a total storage space extending 3m. In reality we envisage this would consist of several compartments being interrupted by the required structural features. The floor covering shall fold outward from the middle and be on a hydraulic system to aid and secure floor cover opening.

Within these compartment spaces aluminium mesh racking is provided. An example of the racking solution is provided as an inset within Figure 21. This provides the necessary mechanical restraint, and prevents stored materials from interacting with or damaging supply services (water, power, data, etc) within the floor space. Furthermore the cage doors shall be secured from unauthorised access using a padlock. Though this rack solution is commercially available (BOC Gas), the unique spatial requirements of the compartment spaces require a custom-designed product. Custom-manufacture of the system should offer considerable cost savings in comparison to a commercially acquired system.

The items occupying the largest volume of storage are the diesel fuel and the waste-handling container. The 50L waste-handling container shall be returned to storage after use. To maximise packing efficiency this 50L container shall be used to store any cleaning products, and tools.

Continuous simulation requires a large supply of diesel (power and incineration). To meet the diesel requirement for (8 people, 1kg/per person/day, 2 weeks simulation) waste incineration requires 112L. Under peak intensity (24 people, 1kg/per person/day, 1 weeks simulation + 1 week normal intensity simulation) the diesel requirement increases to 224L for waste incineration only.

Diesel fuel shall be stored in Scepter® 20L jerry cans. These fit neatly within the allotted large compartment. These shall be stored six-abreast along the length of the large compartment. Combined with the 300L diesel fuel requirement of Martian Designs Power Systems Design Group, 28 jerry cans are required. The six abreast storage configuration maximises the remaining usable space. The combined required diesel fuel (Waste and Power Systems) occupies 50% of the large compartment storage volume.

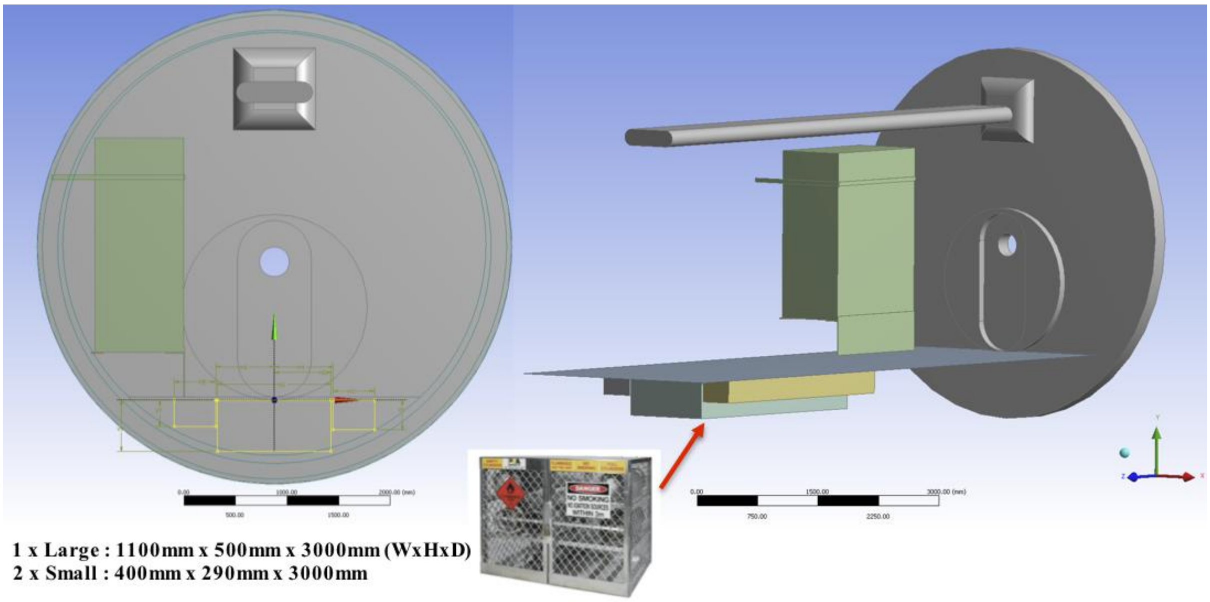

Figure 21: In-floor Storage Space and Compartments

Ventilation and Smoke Evacuation Subsystem

The insertion of an incineration unit within the confined space such as the cargo-bay presents a unique set of design challenges. While the incineration unit is flued (emissions directed outside) and shall be provided with a segregated air-inlet, the incinerator will introduce a high thermal load (conductive, convective, radiative) within the cargo-bay space. This would render the cargo-bay unacceptably uncomfortable for a machine operator. Moreover, as a high-temperature combustion process, the potential for system failure or accidental or inadvertent misuse leading to fire-outbreak or smoke-release must be considered as this poses a life-threatening risk.

Ventilation of the cargo-bay can address many of these concerns, in addition to meeting the expressed ventilation requirements under Australian Standards. To this end Martian Designs have developed the following ventilation concept. The ventilation concept is illustrated in Figure 22.

To effectively ventilate the cargo-bay under all conditions an electrically powered ventilation system was sought. Although passive ventilation systems offer a lower energy operation, these are dependent on ambient wind and temperature. The Colt® W-Liberator Powered Ventilator, is a wall mounted louvered exterior ventilation and smoke extractor. This unit achieves airflow rates of 2.6 m^3/s; a rate equivalent to more than 100 air changes per hour, and meets the requirements of Australian Standard 1668:1, The Use of Ventilation and Air Conditioning in Buildings.

Replacement air is introduced through actuated vent holes. Motorised dampers are used to affect and control the opening of the vents. This allows the cargo-bay to resume the usual self-contained character after waste incineration is completed. These vents shall open automatically as the extractor comes on, in the event of fire, smoke detection or atmospheric contamination.

The design conceives of a roof mounted ducting system. The effect of this is to direct airflow and any smoke upward and through the ducting, rather than being dragged forward through the entire compartment.

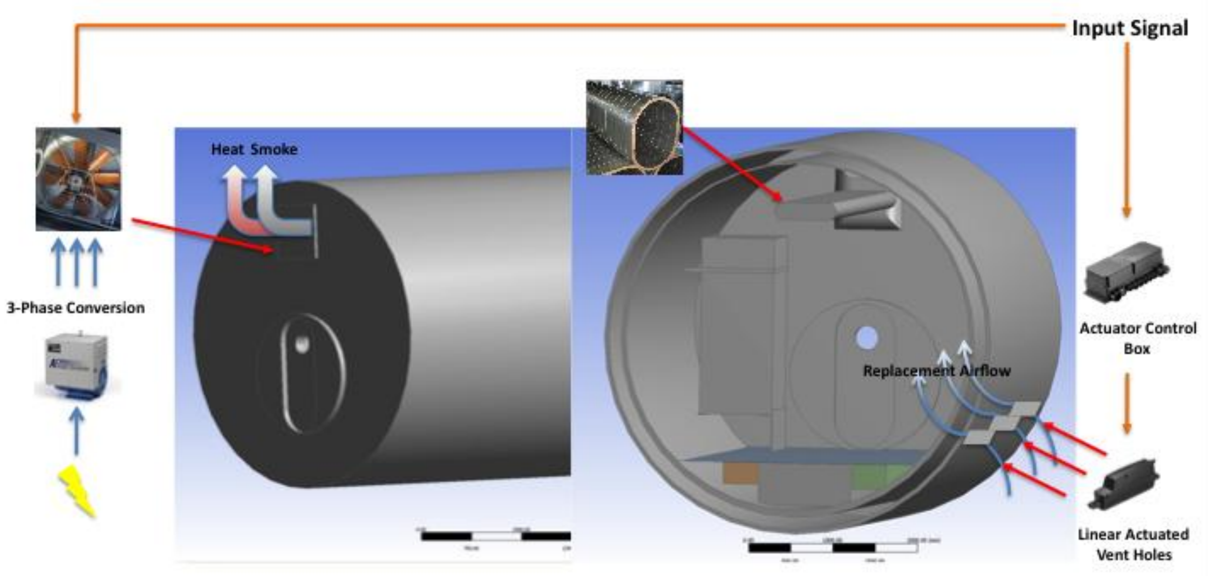

Figure 22: Ventilation and Smoke Evacuation Concept

Fire Safety Subsystem

As the incineration setup uses a high-temperature combustion process, the potential for system failure, accidental or inadvertent misuse of the incineration equipment leading to fire-outbreak or smoke-release must be considered. In this case the means to detect and respond to that risk must be considered. An alarm system must be installed that meets the requirements under Australian Standards. Furthermore, the system design must also consider that any emergency response to an incident of fire, smoke or asphyxiation, given the isolation of Arkaroola, must be performed by the crewmembers themselves.

After consultation with Wormald, an alarm system using ‘conventional architecture’ was decided upon. The conventional system architecture type uses ‘zoning’ to establish lines of detectors, sensors, switches and outputs. When any sensor is tripped the overall zone alarm is triggered. Conventional systems are cheaper and more appropriate for small buildings, and for the MARS-OZ system generates an alarm system within budgetary constraints. A diagram of the conventional system architecture is presented in Figure 23.

From the central Fire Indicator Panel (FIP), which services the entire MARS-OZ infrastructure, the cargo bay is currently designated Zone-1. A T-Gen50 (tone generator) is required to generate automated sirens and audible warnings. A string of detectors including thermo-chemical detectors (heat & CO gas), manual call points, sirens, warning light are envisaged. Additional gas detection is included to monitor the under-floor storage space and ventilation space.

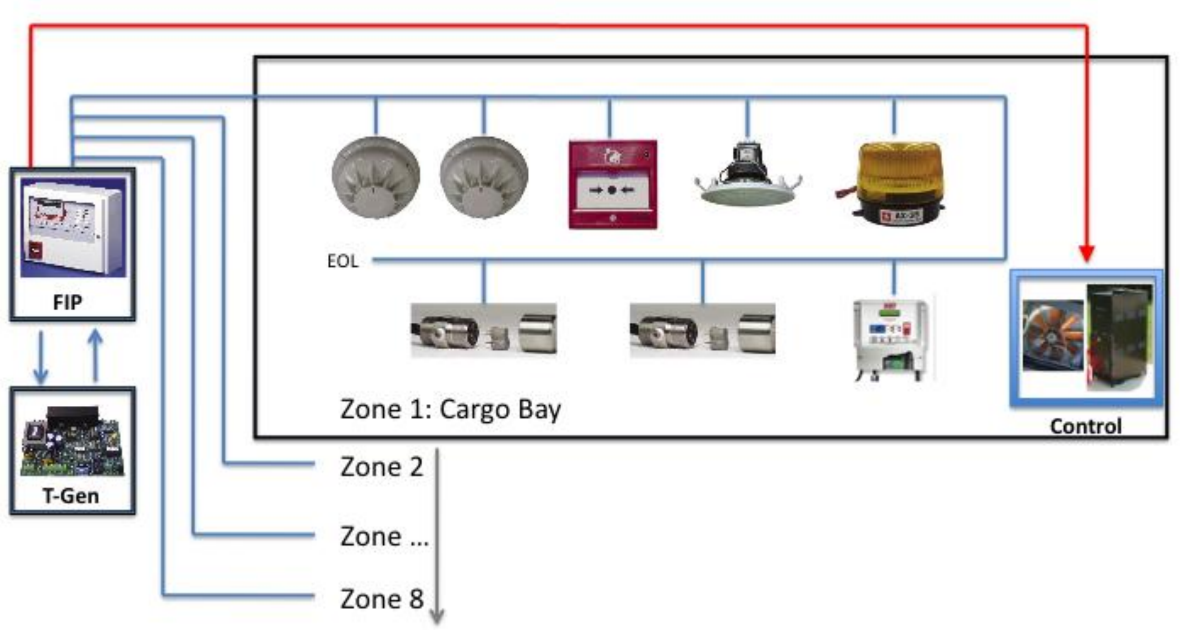

Figure 23: Fire Alarm System using ‘Conventional Architecture’

The FIP can itself affect automated actions such as turning ‘off’ equipment (the incinerator) whilst turning ‘on’ equipment as well (ventilation and smoke evacuation). In the event that the cargo-bay were to fill with smoke, it is entirely possible that the incinerator operator could be rendered incapacitated. As emergency response from the authorities is impractical due to remoteness of Arkaroola, a fire safety system must also include the equipment and procedures for dealing with fire, heat and asphyxiating environments.

A single set of 'turn-out' gear is hence specified to allow an appropriately trained crewmember to perform a rescue in an emergency situation. A self-contained breathing apparatus (SCBA) that has been designed for shipboard (marine) and confined space fire fighting is included. The means to extinguish fire (fire blankets and fire extinguishers) are considered. Due to the aluminium construction of the cargo bay and the presence of electrical equipment, a dry chemical foam extinguisher (type ABE) is specified.

Workplace Integration Subsystem

The systematic means to integrate the incinerator into the workplace has been considered in the workplace integration subsystem. This subsystem consists of the equipment required to meet the various Occupational Health and Safety (OH&S) aspects identified in pre-conceptual studies. These include the various workplace signage required. Design envisages sourcing these from BOC Gases as off-the-shelf items. Occupational medical equipment required by South Australian and Federal Law is provided in a wall-mounted first aid, eye and burn aid kits.

Waste Incinerator Integration Subsystem

Incinerators such as the Mediburn-20 are self-contained incineration units with few external requirements outside of fuel (diesel) and electrical power. The only other key requirements (specified by Elastec Inc.) for the Mediburn-20 are for a level base upon which to operate and surrounding clearance of 2m. In the current circumstance, the former requirement is reliably provided in the form of a footing and restraint system; however the later is spatially impractical to meet. In addition, flue system integration and a segregated external air inlet are required.

To protect the aluminium cargo-structure from any hot surfaces of the incinerator requires the use of a high-specification insulation material. In the current case we propose FIBERMESH-820 and FIBERTEX-820 Rockwool blanket and board insulation. This type of insulation is used for high-temperature process equipment (reactors, ovens, heat exchangers, pipes) and is tested for continuous duty under 820°C heat sources. All cargo-bay surfaces within 2m should be sufficiently protected from the incinerator. Detailed simulation and prototype testing would be required to prove that any insulation scheme was safe and effective. Airflow provided by the ventilation should also be considered as to enhance the cooling affect.

Cleaning Subsystem

All stages of the collection, transportation, processing, and destruction of waste inevitably create soiled surfaces. The possibility for spillage must also be considered. A cleaning system is envisaged to provide the means by which these will be dealt with. Regular operational cleaning of equipment such as the incinerator is a particular concern. For general surfaces, a mop bucket and wringer is provided in combination with disinfectant solution. The cleaning solution was selected for the high-performance, biodegradability and non-toxicity. For more abrasive treatment scouring pads are provided. For the incinerator we propose an aluminium ash storage container, which contains a small shovel/scoop and wire brush that can be used to clean the furnace of residual ash. A small, wall-mounted vacuum cleaner is provided within the cargo-bay conveniently located to deal with spilt ash.

5.2.3. Dry Waste Incineration Back-up System

Should the insertion of an incinerator within the cargo-bay prove to be infeasible, a backup option exists in the form of the Cyclo Burn portable incineration unit (Figure 24) manufactured by Scholer Industries Pty. Ltd. (Australia). The Cyclo Burn system consists of a standard 55-gallon (205L) cylindrical drum (600 mm x 850mm). An electrically powered fan unit (1.6 kW) sits on top of the unit. This uses a 3-pin plug (240 V AC). 50m Extension cords (15 Amp) are required, such that the portable unit can be relocated from the cargo-bay. 200L of waste can be added to the Cyclo Burn before incineration is required. Combustion is driven entirely by the calorific value of the waste. This limits the waste incineration types to mainly dry waste (minimum of 80%). The manufacturer does not guarantee the environmental compliance of the system. A complete system would be comparatively cheaper than the previous fixed incineration setup ($6000).

Figure 24: Cyclo Burn Portable Incineration Unit

5.2.4. Human Waste Incinerator System

The following subsections identify the key subsystems for the human waste management system. These introduce the key system equipment and the integration of these. Equipment included consists of the waste processing subsystem, power subsystem, the ventilation and fire safety subsystems, cleaning and maintenance subsystem and the workplace integration subsystem.

Waste Processing Subsystem

The system chosen to process human waste is the INCINOLET Electric Incinerating Toilet®. An INCINOLET system reduces human waste to a small quantity of ash using electrically powered combustion. There are several models of INCINOLET toilets manufactured to service a variety of environments and demands. It was deemed that the most appropriate model is the Model TR. The TR Model is designed for heavy or full-time use for up to 8 people. As there will be two toilet systems installed in the habitat, this will be more than sufficient to manage the human waste for the 8 inhabitants. Although it may appear sufficient to have a single 8-person toilet, or equivalent, to service the habitat, it is essential that should one toilet fail, the other is capable of servicing the habitat until it can be repaired or replaced. The INCINOLET toilet systems are designed so that they can be installed by the non-expert.

Certain steps must be followed when using an INCINOLET toilet. It is essential for proper function of the toilet that bowl liners be used for each and every use. A bowl liner dispenser must be installed on the wall beside the toilet. An adequate supply of bowl liners must be kept in storage to ensure that the habitat does not run out of them rendering the toilet useless. The bowl liner is to be placed into the toilet bowl as shown in Figure 25. After use, the lid must be closed and the foot pedal pushed. This will release the waste into the lower holding area. Once this is done the start button on the top of the toilet must be pressed after each use.

The heater will operate for approximately one hour and the blower will operate for up to an additional hour. The toilet can be used at any time during this cycle, but the same procedure must be followed exactly, including pressing the start button again. The ash pan below the toilet must be regularly emptied. The frequency of this task depends on the usage of the toilet. This will be elaborated on in the cleaning and maintenance subsection. Signage and instructions outlining proper use of the system should be installed within each toilet room. Further detail of this is in the workplace integration subsystem.

Should it be required that the toilet services a higher number of people for a short period of time, it is necessary to take into account the following guidelines:

1. The ash pan should be emptied before the visiting group arrives.
2. All visitors must be instructed in proper use of the INCINOLET system.
3. The start button must be pushed after every use and an occupant should check regularly to ensure that the toilet is not overfilled.

4. Depending on the usage, one or two extra cycles may need to be run to ensure complete incineration of waste.

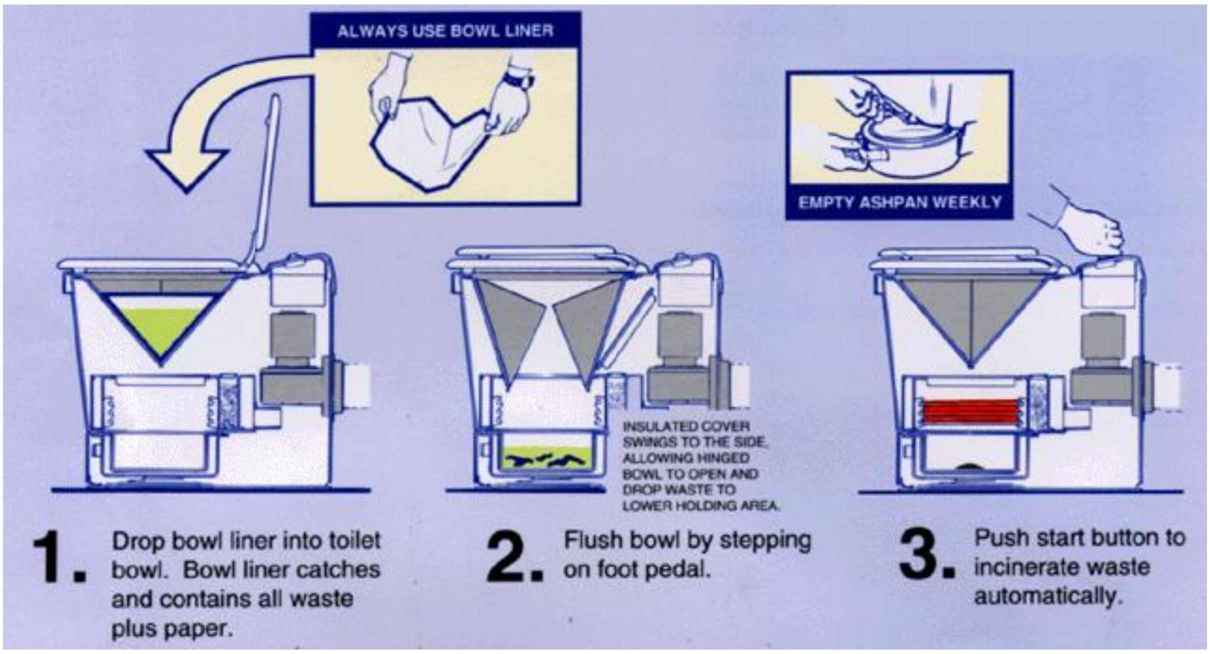

Figure 25: Diagram for using the INCINOLET toilet (Source: http://incinolet.com)

Power Subsystem

Each of the INCINOLET toilets must be supplied by a 240 V AC electrical system on a 20-amp circuit. A 20-amp circuit breaker must be included in this for electrical safety. The power cord for the system is 4 feet in length and hence a power supply outlet must be within this range from each toilet. One complete processing cycle uses between 1.5 and 2 kilowatt hours of electricity. An INCINOLET can, however, be used while a cycle is underway. If this is done, the energy consumption per use is reduced from this.

Ventilation and Fire Safety Subsystems

The INCINOLET toilet systems are ventilated using a ventilation pipe provided with the purchased system. The vent line runs from a vent hole within the toilet through a wall or roof and is ducted to external louvers. As both toilets are on the bottom level of the habitat, they will have to be ventilated directly through the adjacent walls. The vent-line should be terminated externally with a dryer flap or a PVC elbow to prevent back drafting. In exceptional circumstances, such as if there is power failures while the system is in operation, it is possible that smoke and odour may be released into the room. For this reason it is necessary that the room be separately ventilated. The room should not be used while there is no power supply, as both the toilet system and the ventilation will be inoperable. If there is smoke or odour in the room, a ventilation fan installed in the back wall should be used. Such ventilation fans can be easily purchased from a variety of hardware stores.

The INCINOLET toilet systems are equipped with a safety thermostat which shuts off the heater in the system if the air temperature inside the toilet reaches approximately 60°C. There are two other thermostats (the blower thermostat and the limit thermostat) that shut off components when areas reach temperatures that are deemed adequate for processing. Because of these safety measures the risk of the toilet causing a fire in the habitat is minimal; however it is still necessary to plan adequately for the event of a fire. An off-the-shelf smoke and fire detector installed within the toilet room can be considered a sufficient warning system for the inhabitants. Fire extinguishers will be installed throughout the habitat, including outside the toilet room to extinguish spot fires. Should a fire event occur which cannot be simply extinguished, the habitat should be fully evacuated and inhabitants should assemble at a safe meeting point. This should all be outlined in detail in the MARS-OZ habitat fire safety and evacuation plan that shall be outlined in initial training prior to entering the habitat and displayed in various locations around the habitat.

Cleaning and Maintenance Subsystem

The INCINOLET toilets must be kept clean to prevent odour and contamination within the environment. The most important cleaning and maintenance task is to regularly empty the ash pan when the ash is approximately 1/2 an inch (1.25 cm) deep. Excessive ash build-up causes odour, shortens the life of the heater and decreases the efficiency of the system. If the ash is caked and difficult to remove from the ash pan, it may be soaked for a few minutes in warm water. Although the ash does not require further processing, as the quantity of the ash is not large, it may be disposed of into the grey general waste rubbish bins outlined in Section 5.2.2. A small wall-mounted vacuum cleaner may be provided within the habitat to deal with spilt ash. Spillages of human waste must be cleaned up immediately. A mop bucket and wringer is provided to be used with disinfectant solution for this purpose. For efficiency, many cleaning items are shared between the two waste processing systems.

It is necessary that the blower wheel inside the INCINOLET be cleaned every six months. The unit must be unplugged and the top removed for this process to be completed. The inside should be cleaned with a detergent or spray cleaner (pine oil cleaners must not be used). The blower wheel must be removed and cleaned according to the instructions provided by the manufacturer.

Should the INCINOLET system fail or malfunction, it is necessary that the "Troubleshooting" and "Maintenance and Repairs" sheets provided by the manufacturer be easily accessible to the inhabitants along with maintenance and repair contact information.

Workplace Integration Subsystem

In order to ensure proper workplace integration for the INCINOLET toilet, it is crucial that all inhabitants and visitors using the system be familiar with the processes required for operation. Instructions and demonstrations should be included in initial training for longer-term inhabitants. All shorter term inhabitants and visitors should be instructed and have demonstrated to them the required processes. In addition to this, signage should be displayed both inside and outside the toilet room outlining these required processes.

5.2.5. Off-the-Shelf System Components

A complete itemised list of equipment including descriptions, dimensions, operational details, and required quantities of these items is supplied in Appendix IV. Major items (Mediburn-20 and INCINOLET Electric incinerating toilet) are described previously in Section 5.2.1.

5.2.6. Processes for the General Waste Incineration

Installation

Given the weight and bulk of the incinerator, installation issues are of importance. Conceptually, installation seems most reasonable if the majority of the cargo-bay structure is built around the incinerator after it has been inserted. This assists in enabling a high mass lifting solution (crane) to be used. Having completed the reinforced structural supports for the cargo-bay floor the incinerator could be manoeuvred into position and fixed at the base. In this state, the mass of the incinerator and fixed base attachment should provide considerable restraint, though a temporary toppling restraint would have to be considered.

As the structural elements for the cargo-bay wall supports are constructed, the final toppling restraint could be fitted. The necessary insulation to the structural elements should hence be added to protect load-bearing elements. The remaining structure can be constructed as would have been intended.

Transportation

The primary concern of the transportation phase with respect to the incinerator is the affect that both the lateral placement and high mass has on the centre of gravity of the cargo-bay. This will create considerable stresses that will be exacerbated by transport of the habitat upon an uneven road while the structure is being towed to location. Means to mitigate this effect could include temporary load balancing with ballast material. An additional temporary toppling restraint could be considered or the existing system could be enhanced to lower the maximum stress placed on restraint bracket. Transport of the unit should be conducted on a dry-tank basis, to minimise weight and eliminate fire risk.

Maintenance

The Mediburn-20 incineration unit is produced in the United States by Elastec Inc. This creates some difficulty with respect to the immediacy of support services from the manufacturer. However, as the Mediburn-20 is a both a simple and common type of incinerator, 2-chamber diesel fired; there are two immediate possibilities for quick turnaround on maintenance issues. The simple design of the unit makes the unit easy to self-maintain. Minor issues should be surmountable for a technically proficient individual. A second option exists in the availability of local (Australia-based) support services. Expertise for 2-chamber diesel incineration could be sort from Scholer Industries Pty Ltd, who manufactures similar product lines. For major issues, part-failure for example, Elastec Inc. would have to be called. The expense and delayed response make this a least preferable option.

Operations

Waste incineration operations by their nature create a hazardous work environment and should only be conducted by technically proficient individuals. Within the confined space of the cargo-bay the dangers of incineration disposal are magnified. Protocols in how the system is operated can be used to manage this risk.

A system can be enacted whereby incineration is scheduled only when the individuals responsible for incineration and fire-response are both on duty. This ensures a ready-response is always possible when incineration is conducted. The system shall also limit the risk by refusing non-authorised individuals entry into the cargo-bay when incineration is in progress.

Incineration operations shall be delayed for the duration of any large group occupation of the cargo-bay. Dry waste created during this time could be stored and secured within the incinerator itself, due to its capacity of 220L). 50L of waste overflow storage also exists for the generated wet-waste. This is provided in the form of a sealable 50L polypropylene container to be stored in the in-floor storage compartment.

5.2.7. Specifications

The presented concept for the waste incineration system imposes distinct design specifications that must be satisfied before this concept could be translated to a physical reality. These specifications are documented in Section 16: Appendix IV: Waste System Design Verification.

5.2.8. Design Verification

The performance of the conceptual system design for waste management has been verified against the specifications identified in the preliminary sketch plan. This process of verification is documented in Section 16: Appendix IV: Waste System Design Verification.

Preliminary Cost Estimate

The off-the-shelf acquisition cost of all specified components for the General Waste Management System is approximately $58000. This figure does however include various items that are shared over additional systems (fire alarm and response system, cleaning system, etc). Itemised costing of specific equipment can be found in Section 16. Items for which quotes have yet to be obtained are designated TBC (to be confirmed). For current purposes a provisional budgetary estimate an estimate has been made for these items.

Running costs for waste incineration are realised in the consumable inputs used to process waste. These costs are energy inputs, electrical[1] and diesel[2], and material inputs, waste bags and cleaning products. Under intense operation, i.e. with a 24 crew, waste incineration would be expected to cost no more than $20/day.

As all components of the Human Waste Management System are off-the-shelf products a preliminary cost estimate can be easily made. Several of the prices for INCINOLET products are currently in USD, awaiting a confirmation of Australian cost. For the preliminary cost estimate, conversion was not considered necessary, however once the cost is finalised this will be updated. The acquisition cost is approximately $5000. Itemised costing of specific equipment can be found in Section 16. This cost includes a longer-term supply of bowl liners. These should adequately supply the habitat for approximately one year. The running costs of the system, including factors like solar power, should be approximately $25/day.

These costs represent a best estimate; specific quotes should be sought by the client.

[1] Cost of solar power is taken as $0.50/kWh
[2] Cost of diesel fuel is taken as $1.50/L

5.3. Water Recycling System Detailed Design

5.3.1. Design Choices

Water Processing Unit

Due to the cost and size of the Aqua Sun Villager A1, it was judged to offer superior performance to other potable water processors available on the market, as previously assessed in the PSP. The system will be located in the nose of the habitat, in the storage area in the side of the flight deck area. Additional features have been specified for the Villager A1 processing system. These include a voltage transformer and a safety check to cut the system off if the UV light bulb has failed.

Spare parts and an instruction manual will be kept on-site at all times to ensure simple repairs can be conducted quickly and easily by the crew. Spare parts will be located within close proximity to the device.

Aqua Sun is an approved UN supplier and therefore meets the WHO (World Health Organisation) drinking water regulations. Although these regulations are less rigorous than the equivalent Australian regulations, the water produced by the Villager A1 should be processed to an appropriate level of quality to be considered potable.

To manage the accumulation of dissolved inorganic species, an additional processing section was added to the water processing circuit that performs electrodialysis reversal on the Villager A1 water product. This is accomplished using the EDIS N manufactured by EIKOS (Kazakhstan). This unit removes common electrolytes from the water that would not otherwise be removed by the Villager A1 in addition to heavy metal ions. The combination of the Villager A1 and the EDIS N provides a water product that is 'in concept' immediately potable.

In the event where stored and/or processed water fails water quality tests, the device is fitted with a chlorine injection system. Additional chlorine can be injected into the water in order to disinfect it. The crew can add the chlorine to the water supply as required and as specified in the operation manual for the device.

The Villager A1 processes water at a rate of up to 220L/hour, whereas the EDIS N processes at 50L/hour. While it is expected that the Villager A1 shall be required to run for approximately 1 hour each day, the EDIS N shall run for 5 hours drawing Villager A1 processed water from a buffer tank.

Water Storage Tanks

The water storage tanks are located on the top floor of the main habitat module, within the 'flight deck' section. Four tanks are used, one each for fresh water, grey water, and recycled water and a buffer tank between the Villager A1 and the EDIS N.

Each tank is custom designed to fit within the habitat nose, as shown in Figure 26. A walkway of 800mm is left between the tank and the habitat centreline, allowing for access of the flight deck. The tanks are designed to follow the wall curvature, allowing for maximal use of space; piping, pumps and quality monitors will be placed between the tank and wall.

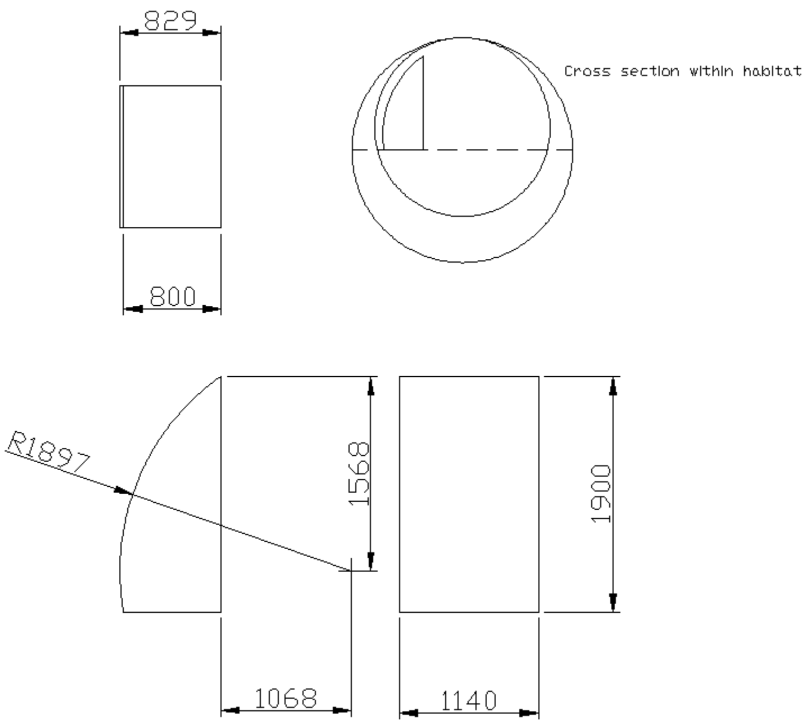

Figure 26: Port-side water tank schematic showing fitment within habitat frame.

The cross section and the length of each tank is constant. Volume requirements are calculated to allow for a 14-day mission without refill, with the possibility of 2-day stoppages in water recycling. This requires at least 864L of fresh water storage, 480L of processed water storage and 384L of grey water storage (consult the Preliminary Sketch Plan for details on the derivation of these figures).

Table 4: Tank Specifications

Tank	Volume (L)	Length (mm)	Inlets	Outlets
Top-up tank	1350	1140	Habitat water input	Post-processing tank
Pre-processing tank	300	260	Habitat water system	Villager A1 Emergency flush
Buffer Tank	200	170	Villager A1	EDIS N
Post-processing tank	1000	425	EDIS N	Habitat water system Emergency flush

Adjusting volumes to enable our chosen water flow processes (see Section 5.3.6) we arrive at a top-up tank volume of 1326L. This allows for using 48 L/day for 12 days, and leaves 750L for emergency use. Using the cross section shown in Figure 26, this requires a tank 1140mm long. The post-processing tank has a volume of 1000L, enabling 4 days of water supply from it, while the pre-processing tank has a volume of 300L. These require lengths of 850mm and 260mm respectively.

The buffer tank between Villager A1 and EDIS N has a capacity of 200L, allowing for a 250L/h rate for the first hour of operations. This tank will need a length of 170mm; alternatively, it could be provided as a separate section of the pre-processing tank.

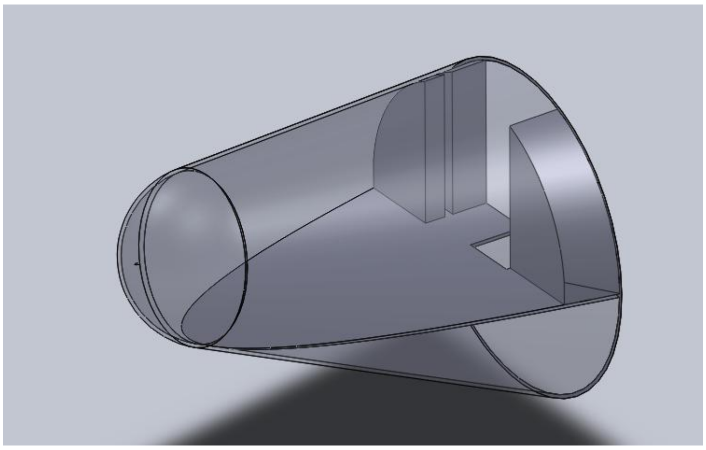

Figure 27: Alternative spacially efficient tank design

An alternative tank design involves a changing tank cross section to completely fill the volume between walkway and habitat hull, as shown in Figure 27. This has a major advantage in removing the dead space between tanks and hull, and provides more room for the flight deck.

However, this design requires a finalised habitat design to gain proper dimensions for. Further, difficulties in manufacture would increase the cost of these tanks compared to the previous design. The Mars Society would have to weigh these pros and cons before choosing which particular design to go with.

To realise the flow profile in Section 5.3.6, each tank needs inlets and outlets to the rest of the system. These, along with tank parameters, are summarised in Table 4.

Each tank has an access panel, enabling direct observation of the interior and placement of tank level sensors within. These panels are located at the very top of the tank, above the 'full' waterline, and contain a sealed interface through which to pass a wire from the level sensor to the habitat computer.

The level of water in each tank is measured using a pressure meter – the Aquameta AN420-5. This device outputs a current signal, telling the habitat computer system how deep the water is in each tank.

Plumbing throughout the MARS-OZ habitat and between the tanks has been deemed outside the scope of this project, and our recommendation is to consult with a professional plumber or hydraulic engineer for pipe routing, hot water systems, and circulation pumps.

Water Monitoring System

Water quality is measured through turbitidy, pH and conductivity tests. These represent the total suspended solids (TSS), acidity or baseness and total dissolved solids (TDS) of the water, and are important parameters of water quality in the Australian Drinking Water Guidelines (NHMRC, 2004).

There are two options for measuring these parameters: manually, by the crew, and autonomously by the habitat computer system. The manual system has a far lower cost, but requires the crew to measure the water and input data themselves, while the autonomous system has a higher price and allows for continuous measurement.

In the manual system, turbidity is measured using the EC-TN100-IR Turbidimeter, pH by the QM1670 hand-held pH meter and conductivity by the EC400 conductivity tester. These are all stored in the lab, where the quality measurements are made every 3 days or as needed. The overall price of this system would be about $1220.

The components for an autonomous system are the RWT-T-100-W-5M turbidity sensor, LT-S410-130/042 pH sensor and WQ301 conductivity sensor. All these sensors have 4-20mA outputs, allowing control through a designated control unit or directly from the habitat computer. The cost of the sensors for this system is around $4220, and a separate control computer would cost around $3000.

Water flow is measured using several flow meters, strategically placed to capture all flows throughout the habitat. These are placed according to Table 5, allowing for the measurement of all rates of interest, requiring 8 separate water meters. We recommend consultation with professional plumbers or hydraulic engineers for this component as well, as these measurements are to be taken within the water distribution system.

Table 5: Water flow meter locations.

Water Source	Water Destination
Top-up tank	Post-processing tank
Pre-processing tank	
Post-processing tank	Kitchen
	Laboratory
	Laundry
	Shower
	Hot water system
Habitat water system	Pre-processing tank

Water Refill System

The water system is designed to operate using a full refill every 2 weeks. The refill will require transport of water from the MARS-OZ base station to the habitat and transfer of the water from a transport vehicle to the storage tanks.

Transport is accomplished through a removable 2400L custom-designed water tank mounted on the tray of a utility vehicle. The design of this particular tank has been left to subsequent design work. The volume must be sufficient to fill both the top-up and post-processing tanks to their maximum, as outlined in section 5.3.1.

Water shall be transferred using a flexible hose between the utility vehicle tank and the habitat nose. The habitat connector is situated behind an insulated panel, minimising heat loss during the mission. Water is pumped using an external pump carried by the utility vehicle, the XF-92 from Davey Water Products; which shall be powered using 240V AC power from the habitat power supply system.

5.3.2. Components

Aqua Sun's Villager A1


Figure 28: Aqua Sun's Villager A1

Aqua Sun International is an approved United Nations Supplier and a registered United States Department of Defence Central Contractor.

The Villager A1 is designed for use in remote areas to obtain potable water from streams, ponds and rivers. The system is diverse and is able to be adapted to a grey-water recycling environment. It is able to process all required input contaminants to produce potable, good-tasting water for our habitat.

The Villager A1 is a compact system which will fit into the storage area in the side of the flight deck. The system's simplistic design makes it ideal for maintaining the projects low budget, minimal environmental impact, and ease of on-going maintenance and repairs.

5.3.3. EDIS 'N': Electrodialysis Reversal

Electrodialysis Reversal (EDR) offers a simple means by which to desalt brackish water, which has been used on a large scale since the 1950's in the water processing industry (Tanaka 2007) and more recently in the domestic environment (Pilat 2001). The EDR technique for electrolyte removal falls short of the more comprehensive reverse osmosis (RO) desalination process. Whereas RO uses a pump system and semi-permeable membrane to remove electrolytes and particulate matter, EDR uses a semi-membrane in conjunction with an electric field to segregate electrolytes from a continuous flow of water that are present as dissolved species (Na^+, Mg^{2+}, Ca^{2+}, Cl^-, NO_3^- etc). EDR does not remove non-electrolyte species such as dirt or microbial contaminants that would otherwise be removed by RO. The means of removal of these contaminants is realised by the Villager A1 processing unit.

EDR has a number of advantages over RO (Pilat 2001). These include:

1. Lower pre-treatment requirements (only coarse filtering required).
2. Lower frequency of membrane replacement.
3. Lower power requirements (EDR: 1-2.5kWh/1000L instead of RO: 25kWh/1000L).
4. EDR membranes are drying insensitive and ideal for hot environments (RO membranes are finer and delicate must be continuous wetted).

5. EDR membranes are less sensitive to residual chlorine (RO membranes sensitive; chlorine must be removed)

The water product that has been processed by the Villager A1 (pre-filtered, carbon filtered, UV irradiated) should achieve a standard immediately acceptable for subsequent EDR or RO purification (free of chlorine). But for the electrolyte content, and subject to testing the Villager A1 for Australian Standards compliance, the water product would be immediately drinkable.

EIKOS manufactures EDR units to accommodate a range of flow requirements and salt levels (5-1000L/h and inlet salt concentrations up to 45g/L). The EDIS N model provides compact unit with the capability to remove 90% of the dissolved solids (inlet concentration of 3g/L) treating a flow rate of 50 L/h.

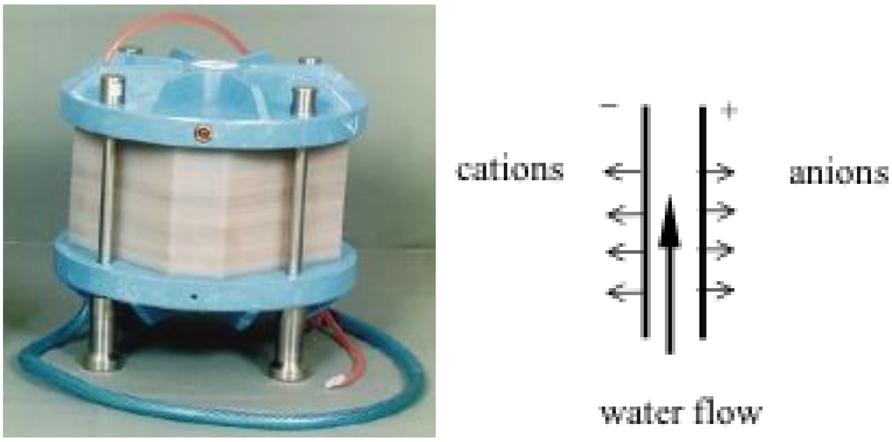

Figure 29: EDIS 'N' (50L/h) EIKOS (Left) and Electrodialysis Process (Pilat 2001)

5.3.4. Water Management System Components

A complete itemised list of equipment including descriptions, dimensions, operational details, and required quantities is supplied in Appendix VI.

5.3.5. Processing & Storage System Positioning

The Villager A1 unit will be located on the flight deck's right-hand side, when viewed from inside. The right-hand side was chosen due to its easier accessibility away from the staircase on the left-hand side. The spare-parts and manual for the Villager A1 will be located directly opposite on the left-hand side next to the switchboard.

The Villager A1 shall be fixed to the tank at floor level to utilise the hydrostatic head provided by the stored water (maximum 1.9m of head). This minimises the risk of cavitation as the quantity of stored water in the pre-process tank is reduced and maximises the useful life of the Villager A1 pump unit. The floor attachment should be demountable to allow the unit to be raised to a temporary holding bracket at a height of 1.5m, for more convenient access for maintenance. The unit should never be operated at this height, and should be returned to floor level in all other circumstances.

The EDIS N unit and the Grundfor NSB 5-33 pump, shall be located at ground level adjacent to the Villager A1 unit for ready accessibility. Water shall be drawn from the bottom of the buffering tank by flexible hose. The specified pump shall increase the energy grade line to a maximum of 33m of head (3.23 bar). This shall be sufficient to drive water passage through the EDIS N electrodialysis unit. Remaining head shall be used to deliver the potable water product to the post-processing storage tank. The EDIS N waste is disposed of using the same water flush-conduit used for the storage tank system, detailed in Section 5.3.6.

Depending on the system requirements for the switchboards, both switchboards could potentially be positioned on one side, and the system and its spare-parts could be located opposite.

The water tanks are located within the nose of the habitat, on either side of the access walkway between the flight deck and mess. Pre- and post-processing tanks are placed on the starboard side of the habitat, next to the kitchen, to allow for easy access to water. The larger top-up tank is located on the port side.

This location leaves room for pumps and other components between the tanks and the habitat wall. Access to these spaces is through panels in the mess/kitchen wall, allowing for maintenance to occur.

The location in the nose of the habitat allows for water collection via tundish from air conditioning units to be achieved with a minimum difficulty, although this particular subsystem is outside of our scope. Although the full water tanks will hold more than 2000kg of water, placement in the nose does not significantly unbalance the habitat; Figure 31 shows a centre of mass analysis of the habitat, using only the outer hull to provide mass apart from the tanks and assuming an equal density. The actual centre of mass will be further from the nose, accounting for equipment, internal walls, fittings etc.

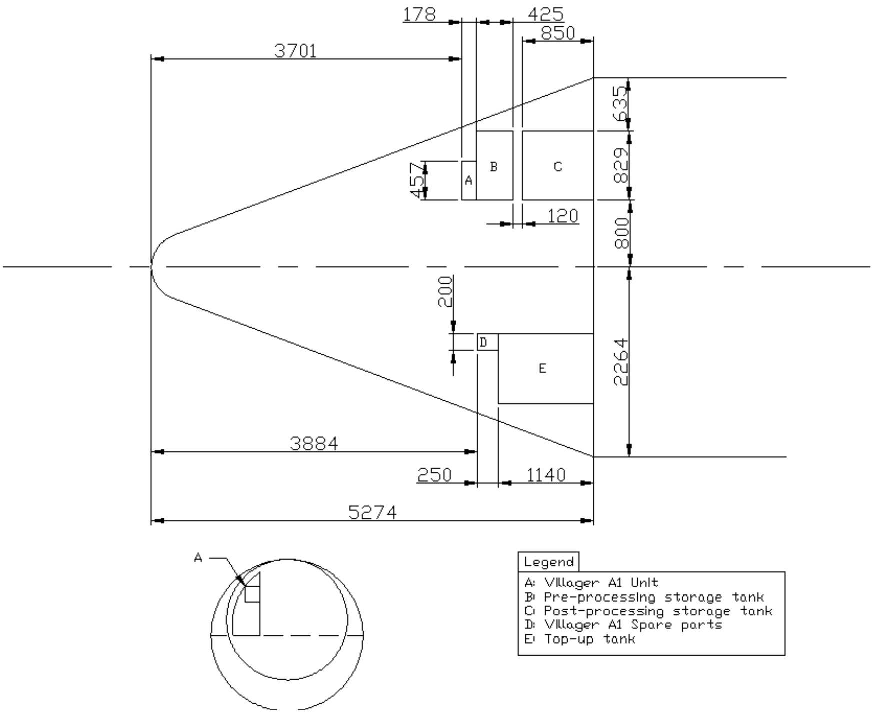

Figure 30: Water system component locations

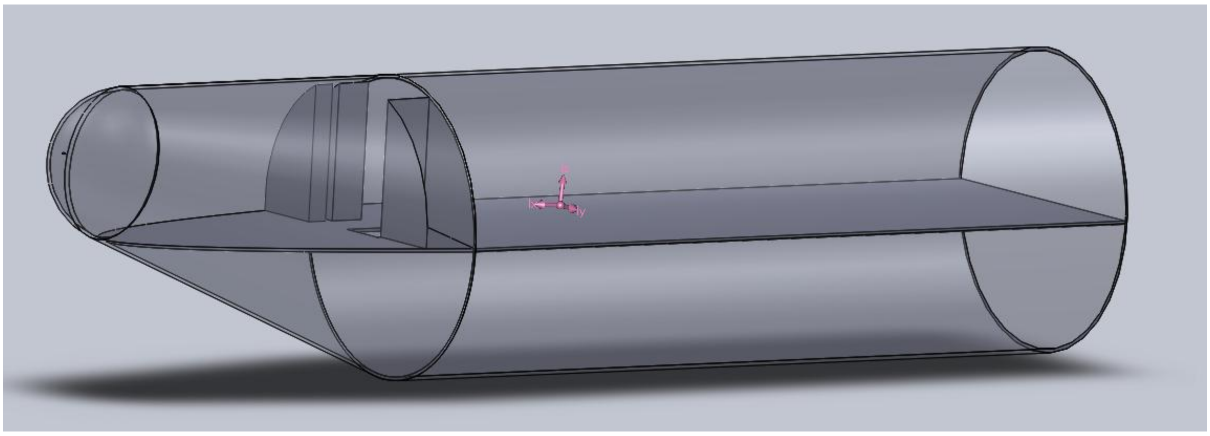

Figure 31: Habitat centre of mass analysis

5.3.6. Processing & Storage System Operations

Installation

Both the Villager A1 and EDIS N are small and compact. Given this, it should be a relatively simple task to position the units within the habitat post-construction. The system is wall mounted (at floor level) and can be moved if necessary.

The water tanks are designed to be a fixture within the habitat. Moreover, the tanks are too large to fit through the habitat external doors, so other options must be considered for their introduction during construction.

Placement of the tanks while the habitat is under construction would be the logical solution. The long lifetime of water tanks makes exchange and replacement unlikely. Structural supports built into the floor would ensure that the filled tanks do not introduce any failure points within the habitat. Design decisions would be subject to mechanical computer simulation.

An alternative installation mode would be to make sections of the habitat hull removable, as for the simulated Mars Ascent Vehicle within the cargo module. This introduces some design complexity to the habitat fuselage, though with the added benefit of permitting replacement should it be necessary.

Detailed Maintenance

Villager A1

The recommended lifetimes of the sediment pre-filter and carbon block are approximately 1 year. This is for usage rates 2-3 times that of the estimated use for the habitat. Given the vital importance of water, and the relatively low cost of these parts, we recommend that these two components be replaced annually, even if they appear to be operating well. The UV light's estimated lifetime is two years. The system contains a cut-off mechanism so that when the UV bulb is out, the system will not operate. This will return a warning on the habitat's Building Monitoring System (BMS) so that the crew is notified to replace the bulb. If the water quality tests suggest that the water is not of sufficient quality at any one time, some of these components should be replaced until the problem is rectified. The results of the test should be indicative of the part that is functioning improperly; for example, bad taste suggests a malfunctioning carbon filter.

Overall, the system's surroundings and casing should be kept clean and free from clutter. This should prevent problems associated with the clogging up of contaminants such as dirt and dust. This procedure should be followed whenever the system is accessed by crews.

EDIS N

The recommended lifetime of the EDIS N membranes is 7 to 10 years, and represents the most fragile part of the electrodialysis reversal unit. After 870 kL 5-10% of membranes require maintenance (Pilat 2001). However as EDR membranes are relatively robust these can be manually cleaned and regenerated by immersing the membranes in an acidic solution (Pilat 2001). This can extend membrane lifetime significantly.

Storage Tanks

The tanks themselves should not need urgent maintenance. Cleaning and tank evaluation will take place between missions, using equipment as advised by water storage professionals.

Instrumentation will be constantly monitored by the habitat BMS. Should an instrument fail, the system will alert the habitat occupants. Spare meters will be stored in the same location as the Water Recycling spare parts (see, Section 5.3.4, Figure 30), with one of each always available. Maintenance will simply involve access to devices and replacement, storing the defective device for repair/disposal.

An exception to this comes in the water flow meters. These are built directly into the water system, so replacement should not be undertaken by the regular inhabitants of the habitat. Instead, if a failure causes water stoppage the water should simply be diverted using built-in valves to allow for a technician to make the replacement.

Water Disposal

Should the water in the post-processing tank fall below specified quality levels, to ensure compliance with federal and state regulatory requirements, the water in both the pre- and post-processing tanks will be removed from the water system. This ensures the health of the crew is never endangered. The EDIS N permeate byproduct shall undergo disposal utilising this common conduit for water disposal.

The water disposal process is recommended by the habitat computer, using the data obtained through the water quality sensors. However, implementation requires the approval of both the habitat crew and the base station control team, reducing the risk of an inadvertent disposal of water.

Water shall be dumped into a separate tailings pool, in the vicinity of the habitat. This pool is kept dry unless needed, and consists of a pit lined with plastic sheeting to protect the surrounding environment. Once here, the water can be evaluated for release into the environment or transport to a safe disposal area using a separate utility-mounted water tank.

After removal of contaminated water, the water circulation protocols are altered. Input from the top-up tank is only required to keep post-processing tank levels above 350L, allowing for two dumping events within a 2-week mission.

Water Refilling

The habitat water supply is refilled using a utility-mounted water tank. This tank is placed on the utility tray at the MARS-OZ base station, filled with potable water and then transported to the habitat at the beginning of every mission. Replacement occurs every two weeks thereafter for any longer duration missions.

Water levels at the beginning of each mission are:

- 1350L in the top-up tank
- 1000L in the post-processing tank
- 0L in the intermediate buffer tank
- 0L in the pre-processing tank

The utility-borne tank contains 2400L of water, enough to transfer all required water in one trip and accounting for all probable losses in the transfer process.

To begin the transfer process, the utility-borne tank is attached to an external water connection that directs the flow to the habitat water tanks. A flexible industrial hose is used.

Water is transferred using an external transfer pump, the XF-92, brought in by the utility. This pump is capable of lifting water 5m to the top of the storage tanks with pumping rate of 90 L/min, makes this a 30-minute operation. Power is provided to the pump from the main habitat power system at 240V AC (50 Hz). A power outlet is provided the same location as the water connection with circuit breaker safety provided internally.

The external water connection goes directly to the top-up tank. Fill-up happens in three stages. First, the top-up tank is filled to its capacity, as monitored by the habitat BMS. Once the capacity is reached, pumping stops by control of the habitat's power output. The BMS then transfers 1000L from the top-up tank to the post-processing tank at its peak rate. Once this is done, the top-up tank is filled again; this ensures that neither tank is overfilled. The autonomous nature allows the rest of the habitat to be configured while the process is occurring.

Water Quality Management

Water turbidity, flow rates and tank levels are all measured autonomously by the habitat computer system. This system collects and stores the data for use by Mars Society Australia, and brings any problems in the system to the attention of the crew through alert messages.

PH measurements are completed every 3 days and are performed manually by the crew using the laboratory facilities. A crewmember uses the QM1670 handheld pH meter to evaluate a sample of water taken from the general habitat system. The result of this test is input to the BMS, allowing for storage and comparison of data.

Overall Operations

The overall operation is comprised of 8 different functions. Six of these functions form the underlying water processing cycle that occurs within the habitat and under simulation. Permeate disposal occurs outside the habitat and represents a water loss (up to 20% of usage per day). To maintain water levels, 'top up' water is provided to the cycle by means of an auxiliary top up tank. This out-of-simulation analogue is in place of a more efficient water reprocessing cycle.

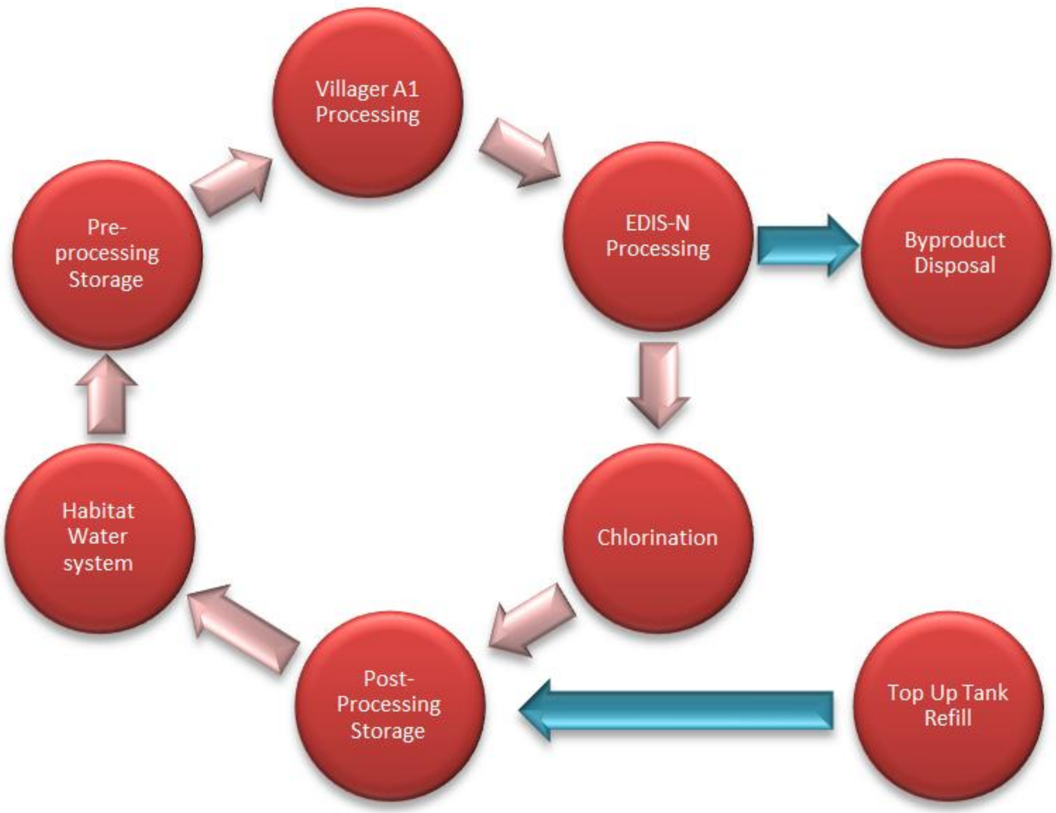

Figure 32: Water Reprocessing Overall System Operations

Water Circulation Processes

Water circulation is controlled by the BMS, using the water level readings from each tank to provide feedback about the current state of the water system. The system is designed for a daily load of 240 L/day (30L per person per day for 8 people) and overall system losses of 20%. A system loss of 10-20% is expected for the EDR unit.

Although the EDR unit uses up a significant part of our water loss budget, this is mitigated by several factors. The water storage was designed to provide extra water using an upper estimate for water consumption, leaving room for these losses within the system. Also, the low concentrations of dissolved solids likely to be recycled will result in a lower amount of water loss from this unit than predicted. As such, the water system will be capable of operating with this extra loss.

The overall water circulation system is outlined in Figure 32. Water throughout the habitat is drawn from the post-processing tank, and grey water from the system is fed into the pre-processing tank. This tank holds water until it can be fed through the water processing system, which leads back to the post-processing tank.

The post-processing tank has a 1000L capacity. It is designed to provide at least 3 days of water supply in the case of water recycling failure. This requires more than 750L to be stored at any time ready for use; if the level drops below this, fresh water is added to the tank from the top-up tank until it stores more than 900L of water.

Water is not stored in the pre-processing tank for more than 24 hours. The level of water in the tank is kept below 100L by controlling input into the water processing system; however, in the case of a processing breakdown, the tank can store 2 days of water before needing to be flushed.

Levels in the top-up tank are not of concern unless they drop below 500L. In this case, a warning is sent to the habitat occupants and base station about low water levels. Another warning is sent when this level drops below 250L, requiring urgent water refill.

Processing Operations

Within the current scope of the project, water processing has two active processing units. The villager A1 shall draw water directly from the pre-processed tank at a rate of 220L/hour. The Villager A1 draws 48W of power at 240 V AC. The water product of the Villager A1 unit shall be delivered to a 200L buffer tank.

When the level of the tank reaches 50L the EDIS-N electrodialysis system is activated. This unit processes water at a rate of 50L/hour. Accordingly the Villager A1 shall cycle between ‘on’ and ‘off’ states as the Buffer tank is filled and then slowly emptied by the EDIS unit to its original level. Processing requires between 1.2 and 2.5 Wh/L in regards to the dialysis energy requirement (Pilat 2001). The power requirement for the pump unit is 0.75kW (Grundfos NBS 5-33). Sufficient head is assumed to remain after EDIS processing to deliver the water product to post-processing storage.

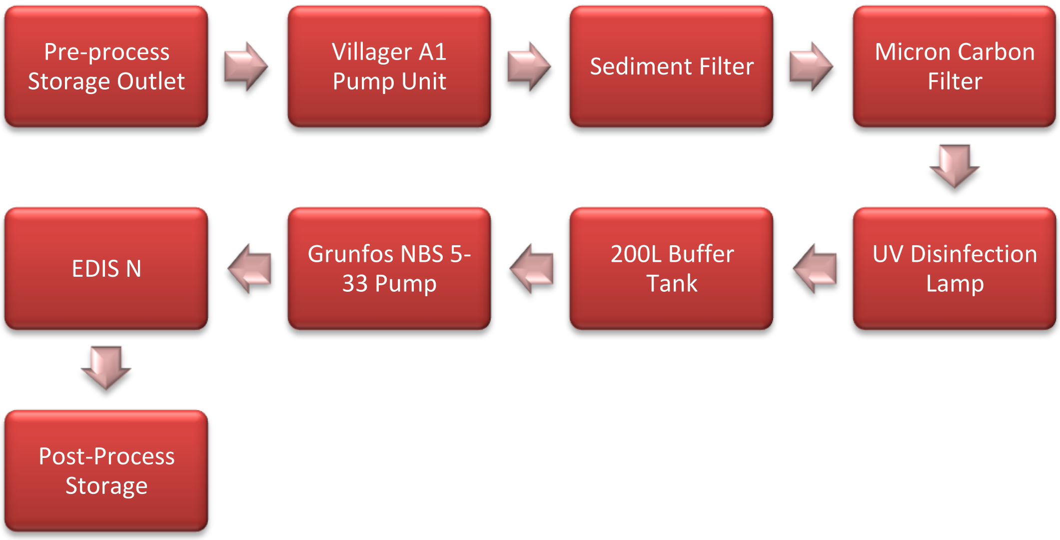

Figure 33: Active Processing Operations

5.3.7. Specifications

The presented concept for the water processing system imposes distinct design specifications that must be satisfied before this concept could be translated to a physical reality. These specifications are documented in Section 18: Appendix VI: Water System Design Verification.

5.3.8. Design Verification

The performance of the conceptual system design for water reprocessing has been verified against the specifications identified in the preliminary sketch plan. This process of verification is documented in Section 18: Appendix VI: Water System Design Verification.

5.3.9. Preliminary System Costing

Water Processing Units Preliminary Costing

Table 6: Villager A1 Costs

Villager A1 Cost	
Component	**Cost**
Villager A1 Unit	USD $1500.00
Lamp Out Pump Disconnect	USD $250.00
International Voltage Converter	USD $400.00
Total	**USD $2150.00**

Table 7: EDIS-N Costs

Villager A1 Cost	
Component	**Cost**
EDIS N Electrodialysis Reversal Unit	TBC
Grundfos NSB 5-33 Pump	$ 400.00
Total	**$400.00**

Replacement Kit

We recommend the initial purchasing of a replacement kit containing spare-parts. An additional ultraviolet bulb should also be ordered, since if one part breaks, there should always be at least one more spare available in addition to the replacement place. Parts need to be shipped in from the USA. Sufficient lead-time is required to cope with the delay in ordering new parts.

Table 8: Replacement Parts Kit Cost for the Water Reprocessing System

Replacement Parts Kit		
Quantity	**Part**	**Cost**
8	Sediment Filters	USD $20.00 ea.
4	0.5 Micron Carbon Block Filters	USD $45.00 ea.
1	Ultraviolet Bulbs	USD $65.00 ea.
1	Spare Ultraviolet Bulb	USD $65.00 ea.
1	5L bottle of Chlorine (Liquid Chlorine)	AUD $9.49
Kit Discount		-USD $25.00
Total		**USD $455.00**

Ongoing Costs

Replacement parts can be purchased individually as required. It is expected that the carbon block and sedimentation pre-filter would require replacing once each year and the UV bulb every three years.

Table 9: On-Going Costs of the Water Reprocessing System

On-Going Costs		
Item	**Numbers of Times Replaced/Year**	**Cost (Approximately)/Year**
Sediment Filter	1	USD $20.00
Carbon Block Filters	1	USD $45.00
Ultraviolet Bulbs	0.33	USD $22.00
Total		**USD $87.00/year**

Shipping

Table 10: Shipping Costs of the Water Reprocessing System

Shipping Costs		
Item	**Company**	**Cost**
System & Replacement Kit	Seven Seas WorldWide (SevenSeasWorldWide, 2011)	USD $215.00
Spare Ultraviolet Bulb	Seven Seas WorldWide	USD $10.00
Total		**USD $225.00**

Installation

Installation of the system is simple. The system comes pre-wired and with all internal plumbing completed. The system simply needs to be connected to the power-supply, and the water-inlet and water-outlet hoses (provided) connected. It is assumed this could be done without significant cost by volunteer work.

Table 11: Overall Costs of the Water Reprocessing System

Initial Costs	
Aspect	**Cost**[3]
Villager A1 Device	$2150.00
Spare-Parts Kit and Bulb	$455.00
Shipping	$225.00
Installation	$0.00
Total	**$3230.00**
On-Going Costs	
Replacement Parts	**USD $87.00/Year (AUD $84/year)**

Water Storage Preliminary Costing

The main costs for the water storage system are component prices. Costing currently assumes installation shall utilise volunteer labour. Shipping prices are not included, as the location of construction is not known.

Separate costing is given for both the autonomous and manual measurement systems; only one of these costs will be followed in the final design of the Mars-OZ habitat.

These prices are a conservative estimate only, involving up to 10% overhead from given cost to account for price fluctuations or design changes. Replacement parts are assumed needed once every 2 years as a worst-case scenario. All prices are given in AUD as of 28/10/2011.

[3] Assume AU$1:US$1 currency conversion

Initial Costs

Table 12: Water Storage System Cost of Acquisition

Component	Supplier contacted	Individual cost	Number required	Total cost
1. Component Costs				
Custom-designed Water Tank	Ajay Fibreglass Industries Pty Ltd	$3 000	5	$15 000
Aquameta AN420-5 Pressure Sensor	Anadex Labs Pty Ltd	$400	4	$1 600
Flow Meters	N/A	N/A	8	N/A
Davey Water Products XF-92	Aquatrad	$300	1	$300
20m Blue Layflat industrial hose	Aquatrad	$3.96/m Quote received 3/11/11	1	$80
Total				**$16 980**

Table 13: Autonomous Water Monitoring System Costs

Component	Supplier contacted	Individual cost	Number required	Total cost
RWT-T-100-W-5M Turbidity Sensor	Royce Water Technologies	$2 960	1	$2 960
LT-S410-130/042 pH sensor	Royce Water Technologies	$580	1	$580
WQ301 Conductivity Sensor	Global Water	$679	1	$679
RWT75 Controller	Royce Water Technologies	$2 980	1	$2 980
Total				**$7 199**

Table 14: Manual Water Monitoring System Costs

Component	Supplier contacted	Individual cost	Number required	Total cost
EC-TN100-IR Turbidimeter	Instrument Choice	$1 059	1	$1 059
QM1670 Handheld pH Meter	Jaycar Electronics	$60	1	$60
EC400 Conductivity Tester	Global Water	$98	1	$98
Total				**$1 217**

On-Going Costs

Table 15: Water Reprocessing Operational Costs

2. Ongoing Costs				
Buffer refills for QM1670	Jaycar Electronics	$10	2/year	$20/year
Replacement AN420-5 Pressure Sensor	Anadex Labs Pty Ltd	$400	0.5/year	$200/year
Replacement Turbidity Sensor	Royce Water Technologies	TBC	0.5/year	TBC
Total				**$220/year**

6. Energy

6.1. Introduction

Energy systems are a vital part of the MARS-OZ habitat. Without sufficient power generation the habitat would be unable to function as almost all systems within the habitat require electricity to operate. This section of the Final Design Report outlines designs for ensuring the habitat is reliably supplied with electricity. This system provides a detailed analysis of the primary power generation system, backup power generation system, power storage, and climate control. The primary means of power generation and storage is outlined in section 6.2. It is recommended that a solar farm be used for the MARS-OZ habitat, with batteries for storage lasting up to 24 hours.

Alternatives to this solar-power system that were considered but decided against were biofuel systems and wind power. Biofuel systems were rejected due to the scarcity of locally produced biofuel. This meant fuel would need to be imported to meet base demands. Wind power was rejected as wind speeds are relatively modest in the proposed environment and an adequately sized wind generator would not be easily transportable.

It is recommended in section 6.3 that a diesel backup generator is provided for use in emergencies or short or long-term failure of the primary means of power generation.

A number of alternatives to a diesel backup generator were considered including propane and natural gas power stores. Diesel is cheaper and safer than both these options, and is also required for the chosen waste incineration system, and thus is thought to be the best option.

Climate control systems are considered in section 0. Evaporative cooling was an attractive choice given the low humidity of Arkaroola; however the water usage of this option means it is not tenable. A Heating, Ventilation and Air Conditioning (HVAC) system was chosen instead. This has higher level of power use than evaporative cooling, but uses no water and both cooling and heating are accomplished using the one system.

From the design process it has been realised that it is prohibitively expensive to operate the base solely from solar power and stored solar power. Therefore it is suggested that diesel generation be used to supplement power from a solar farm. Diesel can produce power in all weather conditions and throughout the night, considerably reducing the load on the solar farm and the number of batteries required. While costs have not been explicitly calculated for this situation, it is estimated that this could reduce the required quantity of solar panels by approximately half. This reduces the cost of the system from approximately $700,000 to around $350,000.

6.1.1. Scope

The scope of Martian Designs' work into energy management in the MARS-OZ habitat has been refined to ensure the quality and effectiveness of the systems considered. Areas in which the energy management team will focus include:

- Power auditing to determine requirements
- Designing a reliable and effective method of primary power generation
- Designing an emergency backup power generation system
- Power storage
- Power load management
- Designing a climate control system

The overall power generation system has been designed to maximise efficiency and effectiveness whilst minimising capital and maintenance costs. Considerations include external and internal habitat temperatures, reliability, architectural and waste management needs, and ensuring the system is easily transportable.

6.2. Primary Power Generation and Storage

6.2.1. Design Choices

Mars Society Australia has explicitly specified the use of renewable energy sources for the MARS-OZ habitat's power system. It was also specified that any power source had to be transportable. Given the solar-weather conditions in Arkaroola, solar power was chosen as the most suitable choice that satisfied the client's requirements. Solar power is an inexhaustible power source and is extremely abundant in the Arkaroola region. A solar power system can reliably produce between 1 and 1.4 kilowatts of power during the daytime there.

There are two options for creating electricity using solar power; photovoltaic (PV) or concentrated solar thermal power (CSTP). PV is a method of directly converting sunlight to electricity, whereas CSTP focuses the sun's energy to generate steam and hence produces electricity through the use of turbines. CSTP is often used for large-scale power generation; however due to the scale of the necessary infrastructure this would not be viable for the MARS-OZ project. It was therefore deemed that PV is the most economical and technically practical solution for MARS-OZ.

PV installations operate for many years with minimal maintenance or required intervention after their initial set-up. After the initial capital cost of building any solar power plant, operating costs are extremely low compared with other existing power generation technologies.

The PV system would be set up as a 'farm' near the habitat. Panels would be mounted on the ground, with moving bases that are programmed to track the sun throughout the day to gain maximum power generation from the system.

The system will also include a battery array to power the base at night or for other prolonged periods without sunlight. Given that the habitat will be deployed in arid areas it is unlikely that there would regularly be long periods when the system was encumbered by cloud cover. Batteries need only cover short periods of insufficient power supply and balance excess supply with storage. Should solar power be unavailable for long periods, the emergency backup system would need to be used.

PV panels produce a 12V DC current that would be converted to 240V AC (50Hz) using an alternator system. These alternators are chosen such that all appliances power requirements are met.

6.2.2. Components

The best option for implementing the PV system is to buy it as a complete system including panels, inverters, and batteries. This ensures that all individual elements are compatible and also simplifies maintenance issues since there is only one manufacturer and supplier involved. With this is mind the recommended system is based on a 9.5kWh system available from the Rainbow Power Company. To meet the power requirements for the habitat, a contingent of 16 similarly sized systems would be required. The system consists of five components; PV panels, carrying frames, batteries, and two types of inverter.

Photo Voltaic Panels

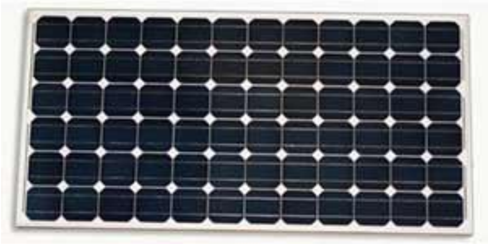

Figure 34: Trina Solar 190W Solar Panels

Figure 35: Solar Frames

For a 9.5kWh system 24 Trina Solar panels are required. To meet the calculated required habitat usage of 250kWh the system would require 384 panels.

Batteries

Figure 36: Raylite 1050Ah Batteries

64 Raylite batteries are required to meet the requirements of the system. Each battery is 411mm long, 262mm wide and 530mm high, giving a per unit volume of 0.057m^2 or a total volume of at least 3.65 cubic metres.

The easiest configuration of batteries would be to have just one layer high, in a 6x8 battery rectangle. This would give a required ground area of about 12 square metres (including space between batteries for access and wiring).

Inverters

Figure 37: SMA Sunny Island 5000 Watt Inverter/Charger

Figure 38: SMA Mini Central 6000 Watt Inverter

The system for the habitat would require 16 units for each inverter.

6.2.3. Specifications

For use of the solar PV system the following maintenance activities are required:

1. Cleaning of solar panels with a non-abrasive cleaning agent to keep the surface free from debris and maximise solar gain.
2. Checking wires and connections regularly to ensure they remain dry and undamaged.
3. Checking solar panel frames for leaks. Sealant must be applied if any leak is found.

6.2.4. Preliminary Cost Estimate

The cost of a 9.5kWh system is estimated to be $43,859. For the given requirements 16 of the 9.5kWh systems are needed. Therefore a preliminary cost estimate for the system is $702,000.

While this cost is high, it is not unreasonable to pay a high cost for a photovoltaic system. This system will run with little maintenance and no requirements for raw materials for up to 20 years, allowing for costs to be somewhat recovered throughout the habitat lifetime. Note that it is estimated that running a diesel generator will cost about $125 per day of operation for fuel, not including shipping costs[4].

It is also likely that a quote to supply such a large system would be lower than this, as the price per unit would decrease as more were purchased. However, it is difficult to obtain such quotes without intending to purchase a system in the near future. The client should seek a more detailed quote for the system before dismissing it on the basis of cost alone.

6.3. Backup Power Generation

6.3.1. Design Choices

Diesel standby generators remain the primary choice for emergency power systems worldwide. Diesel produces more power, costs less to operate, and is less volatile (and hence safer) than petrol. The longer life and lower operating costs compared to petrol engines are what makes diesel engines so popular. Today diesel generators produce virtually no visible smoke and very few emissions of any kind.

Diesel fuel is a light-grade oil. Inside any engine there are many moving parts that create friction. Petrol and propane are solvent-based fuels which promote friction and wear. Diesel, being a lubricant, reduces friction and wear.

In a situation where backup power is being used the habitat would be operating on a low power budget. Appendix A details power usage in an emergency situation, which could be maintained for around 24 hours; and in a low power situation, when the habitat is forced to use backup power for extended periods of time. In the latter case the habitat would be stocked with enough fuel to last a week, after which time the primary power generator would need to be restored, additional diesel delivered, or the mission abandoned. As **Error! Reference source not found.** shows we would need a generator capable of producing around 9kW for low power situations.

[4] Assuming 96L/day diesel usage at 130c/L

Due to the ventilation requirements of a diesel engine the generator would need to be kept outside. While a generator would certainly be built with that in mind and would have a casing that could resist the elements, it is recommended that a small shack could be built around the generator to provide protection from the weather. Such a utility room could be quite rudimentary, and could potentially be constructed from scrap roofing iron and volunteer semi-skilled labour at negligible cost.

So as not to affect the mission simulation, it would be necessary to start the generator in a space suit. As such a simple button-push start would be necessary – anything more elaborate may be difficult in a space suit.

6.3.2. Components

Generator

Figure 39: Kipor KDE13SS3 Generator. Source: http://www.macfarlanegenerators.com.au.

To meet the requirements outlined above Martian Designs recommend the Kipor KDE13SS3 10.6KW Three Phase Electric Start Silent Diesel Generator with a three cylinder, inline 4-stroke, water cooled engine. This unit can generate 10.6 kVA (with an 11.6 kVA peak power output) at 240V. An acoustically treated enclosure minimises operating noise to 51 dB at a distance of 7m on the fixed installation generating sets. The dimensions of the unit are 1570mm x 780mm x 1050 mm and it weighs 685Kg, and 750Kg when fuelled. It has a 12-month/1000h conditional warranty.

Transfer Switch

A standby power backup device connects to the wiring via a transfer switch, which is installed indoors. In standard domestic situations the transfer switch prevents ‘backfeeding’ into utility lines, which is dangerous and illegal. In this case the utility lines would be the primary power generator, and the transfer switch will protect both the primary and backup generators from damage due to overlap of their power supplies.

6.3.3. Processes

Installation

Normally a stationary generator is mounted outdoors on a cement pad. Preferably it is placed near the fuel source. Many models already come with a mounting pad. In any case, a location that is flat and has provisions for water drainage is required. To prevent exhaust gases from entering the habitat, locate the unit in a well-ventilated area away from entrances.

Starting

The recommended generator has a simple push-button start. This process could be performed easily by a crewmember in a spacesuit without breaking the mission simulation. When failure of the power systems is detected a single crewmember would need to go outside to the generator, which will be nearby the habitat, and start it.

6.3.4. Specifications

The diesel generator will require Mars Society Australia to meet the following:

- It will need an electrical connection to the base, via the battery bank
- It will need to be supplied with diesel fuel, oil and coolant
- A flat location with provisions for drainage must be available to install the generator
- It is recommended that a small utility room is built around the generator on location to offer some protection from the elements

6.3.5. Preliminary Cost Estimate

The estimated cost of the generator itself is $13,399. The cost of building a shack around the generator would be minimal, around $100. Coolant and oil would also be required, costing another $100. As such the total cost of the backup power system would be around $13,600. This is only an estimate; specific quotes should be sought by the client.

6.4. Climate Control

6.4.1. Design Choices

A heating, ventilation, and air conditioning (HVAC) system is a climate control system that uses refrigerants and heat exchange to either cool or heat air, which can then be transported to where it is needed using ducting. In the habitat such a system would be built into the structure. It requires no inputs other than electricity, and would be operated by a thermostat with a manual override.

6.4.2. Components

Centralized HVAC

Heat Exchange: The heat exchanger is housed within the main furnace unit. When the system is turned on, via a manual or thermostatic control, electric coils heat air drawn into the air exchanger from the building exterior or through a cold air return chase, which draws cool air from the interior of the building. As the air is heated, a blower pushes the radiated warm air into the ducting system for distribution to the building.

Evaporator Coil: The evaporator coil provides cooled air for the furnace blower to distribute through the ducts or airways. The typical design incorporates metal tubes surrounded by thin aluminium fins, which cool the air in a way similar to the radiator in an automobile. The evaporator coil unit is typically encased within a metal box on top of or beside the furnace, and is connected to the condensing unit positioned outside the building.

Refrigerant Lines

These are copper or aluminium tubing lines that carry liquefied refrigerant from the condensing unit to the evaporator coil and then recycle the vaporized refrigerant back.

Condensing Unit

This part of the HVAC system is typically located outside of the building and houses a compressor that condenses refrigerant gas, cooled by heat exchange with the outside air, to a fluid, and then pumps the fluid through a metal line to the evaporator coil in the furnace unit. As it passes through the evaporator coil, tiny spray nozzles spray the cooling fluid into a chamber. This lowers the pressure and the fluid evaporates back to the gas-phase.

In this process, the evaporation absorbs heat, the air rapidly cools, and blowers force the refrigerated air through the duct system which distributes it to the building. The refrigerant, returned to a gas, is then returned to the condensing unit to repeat the cycle.

6.4.3. Preliminary Cost Estimate

The initial cost of the HVAC system depends on the location size and interior of the habitat. The minimum cost based on a smallest HVAC commercial used system is $15,000, excluding all transportation and installation costs. It is, however, recommended that the client seek a full quote from a supplier should they decide to use this system.

7. Design Integration

Design integration has been a major consideration for the design team throughout the project. One of the main project objectives was to design subsystems that not only worked effectively with the other Martian Designs solutions, but also with the existing habitat design and possible future designs as well.

Figure 40, found on page 96 of this document, demonstrates the network of interfaces and processes that ensure the habitats vital systems integrate together to provide a reliable, high quality and comfortable environment.

7.1. Integration Summary

Figure 40 is an N-squared diagram that graphically represents the integration aspects that have emerged during our analysis and design process. Interfaces that are electrical or communication based are highlighted in red, hydraulic interfaces in green and mass/airflow and protocol based interfaces appear in yellow

7.1.1. Power Generation Interfaces

The N-squared diagram highlights a number of interfaces between the solar array, diesel generator, voltage converter and batteries that are isolated from the rest of the habitat. This power generation system works to power ever other system within the habitat.

Both the solar and diesel power generation are linked to the voltage converter and batteries. All power needs to be converted to a useful voltage and stored in the batteries for use at peak times. The batteries are also linked back to the diesel generator, as when the batteries are low the generator will provide more electricity to charge the batteries.

The other significant interface related to power is the connection of the batteries to all services and systems within the habitat. This is demonstrated by the row of interface connectors that link the batteries to every other subsequent system on the diagram.

7.1.2. Climate Control and Ventilation

The climate control and ventilation systems are linked to every space within the habitat in different capacities. All living spaces are conditioned while areas such as the INCINOLET and waste incinerator areas are mechanically ventilated only. By only ventilating these areas and not conditioning them the load on the HVAC system is minimised and power is saved.

As part of the complete air-conditioning and ventilation system there are feedback loops from all spaces to the control system. This feedback will be in the form of communication between the HVAC system and sensors in the rooms. These sensors will be determined by the final habitat design team, but could include temperature sensors, CO_2 and CO sensors and even automated self-conditioning technology such as mechanically opening windows.

7.1.3. Fire Protection Services

Fire protection is often overlooked during preliminary design phases, but Martian Designs considered occupant safety a high priority. The N-squared chart shows feedback links from all rooms and internal equipment to demonstrate the communication between fire detectors and the fire protection control system.

The fire protection control system is linked back to the HVAC system. This vital communication link ensures that when a fire is detected, the ventilation system transfers into smoke-mode. Smoke-mode is a Building Code of Australia (BCA) requirement in larger buildings but can be used effectively in smaller structures to suppress the spread of fire. This works by shutting off air flow to spaces where flames are located with the intention of 'suffocating' the fire. This can also aid in then clearing smoke out of spaces that do not contain flame to assist fire-fighters and aid clean-up once the fire is extinguished.

7.1.4. Waste Management Integration

There are specific areas in the habitat that are directly linked to the waste management system. The kitchen area produces a considerable amount of food and packaging waste that must be transferred to the incinerator. There is also a link from the laboratory area to the incinerator, as other waste will be generated in the laboratory that needs to be disposed of.

Another obvious interface is that between the bathroom toilet and the INCINOLET. Technically the INCINOLET system will be located within the bathroom space, but the installation of the INCINOLET will need to be integrated with all other hydraulic and electrical services in the area.

7.1.5. Hydraulic Interfaces

There are a number of important hydraulic based interfaces that need to be considered throughout design and construction of the habitat. The main components of the water management system are the water pumps, the AquaSun and EDIS-N water processing system and the water storage unit. The processing circuit and the storage tanks are linked through the pumping system to control the flow of water.

The water storage tanks feedback into the water pumps, which in turn supply all water consuming areas of the facility. There is also a controls aspect of the water storage and AquaSun interface, as when the storage tanks are full there is no point in running the AquaSun and so water can be sent to backup storage or disposed of.

7.2. N-Squared Diagram

The following diagram demonstrates the interfaces and processes that have been outlined above. An N-squared diagram represents functional or physical interfaces between different system elements. Each arrow represents an interface, and the coloured dots represent where the links between elements lie. The lines on top of the diagram represent inputs from one system to the next, and the lines on the bottom of the diagram indicate feedback loops.

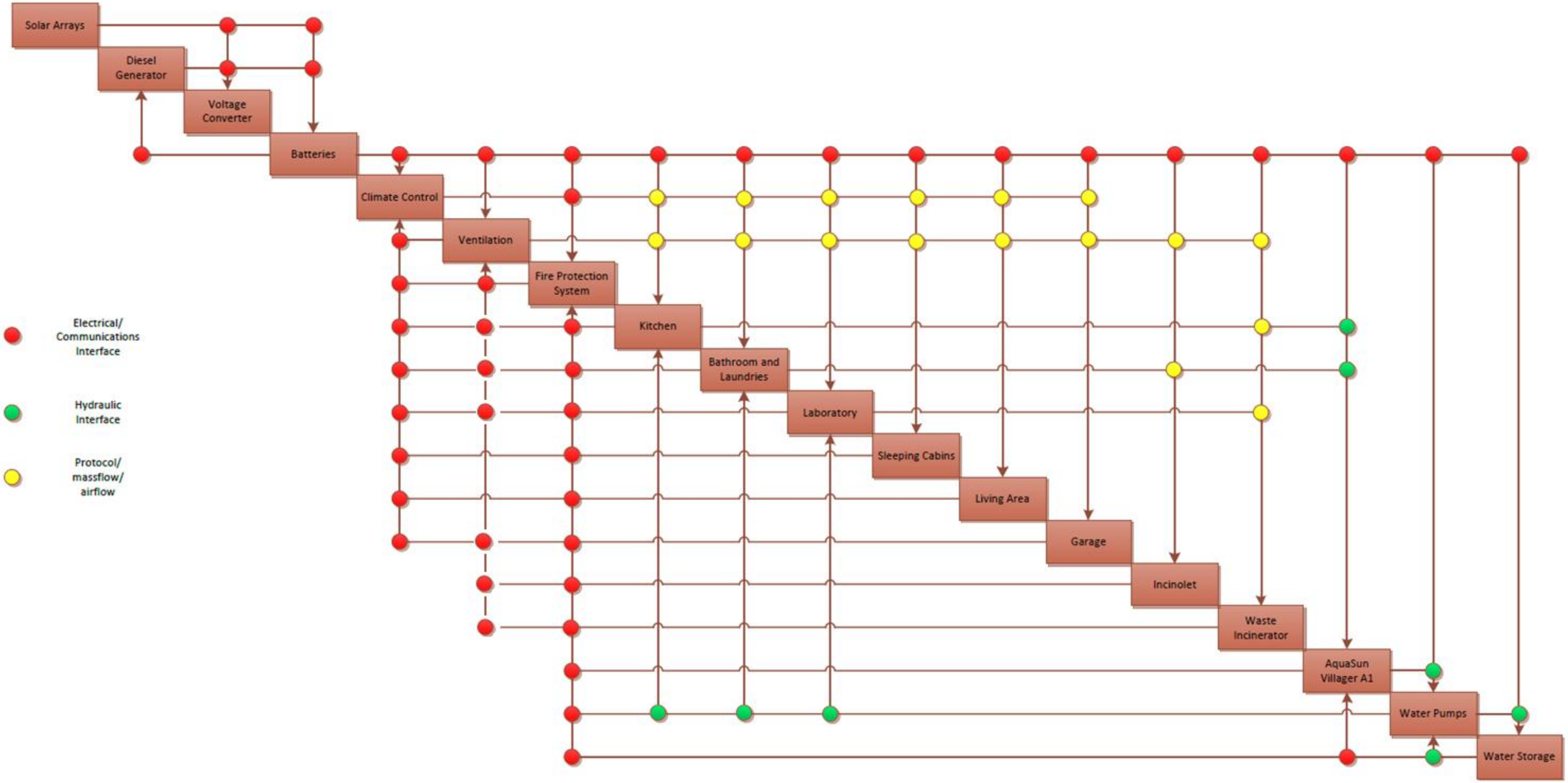

Figure 40: N-squared chart demonstrating design integration and processes

8. Cost Summary

The following section summarises the cost analyses of all design solutions within the current project scope. It should be noted that this is not a quote, but instead provides a preliminary cost estimate based on the information available to the design teams. The costs are summarised in Table 16: Overall Cost Summary.

Table 16: Overall Cost Summary

Initial Costs	
Item	**Cost**
Bed/Desk System	$10, 000
Internal Wall System	$7, 200
Water Supply System	$30, 000
Waste Incinerator	$65, 000
INCINOLET System	$5, 000
Diesel/Solar Hybrid Power System	$365, 000
HVAC	$15, 000
Total	**$497, 200**
Remaining Habitat Budget	**$202, 800**

There are a number of factors that will greatly affect this costing estimate. Some of these factors include:

- Conservative energy estimates and lack of reliable quotes
- Labour costs
- Location based costs
- Occupants ability to follow equipment protocols

The energy estimates that have been used to provide an estimate for photo voltaic power generation were very conservative; however, Martian Designs believe that paying this much for a completely independent, remote and long lasting power source is not unreasonable. However, given the circumstances and budget of the MARS-OZ project, it is recommended that a diesel generator be used to provide a substantial amount of power.

Labour costs may increase or decrease costs depending on the nature of the design solution. For example the cost of the internal walls currently does not take into account additional costs for labour and manufacturing. For now the design envisages that fabrication should be possible using voluntary unskilled labour.

On the other hand, manufacturing and installation costs can be significantly increased simply due to the location of the habitat. The fact that the habitat is being manufactured before transportation to site remedies part of this problem, but some items are still going to need to be tended to on site. The remote location will adversely affect these costs.

The complexity of the final design will also have an effect on costs. If all walls, floors and other void spaces are packed full of building services then the manufacturing of the habitat will become much more complicated, and consequently incur additional costs. Martian Designs recommends that the simplest final habitat designs should be utilised to minimise the potential impact of this factor on cost.

The ability of the occupants to follow the expressed equipment protocols can directly affect the cost of the habitat. Where the crewmembers are improperly or incompletely trained, oversights and accidents can occur. This can incur damage to the systems at considerable expense. For example improper instruction in how to install walls or how to use the INCINOLET toilet, among other items, can lead to damage which would result in costly repair or replacement.

Aside from the photovoltaic power system, the system designs created by Martian Designs provide an economically feasible project. These utilise a reasonable and realistic portion of the MARSOZ Habitat budget. Mars Society Australia nominated a $700,000 budget total for the construction of the habitat, and the portion of this budget taken up by our crucial designs is highlighted in Figure 41.

It should be noted that a reasonable portion of the total budget is expected to be used on the systems provided by Martian Designs. The section highlighted in green is the portion of the budget that will remain to be spent in other areas. This is a very positive result, seeing as crucial systems such as water and waste management, air conditioning, privacy and power generation have been included.

It should be noted that a diesel/solar hybrid system has been used for the purpose of price estimation and the budget portion graphic Figure 41.

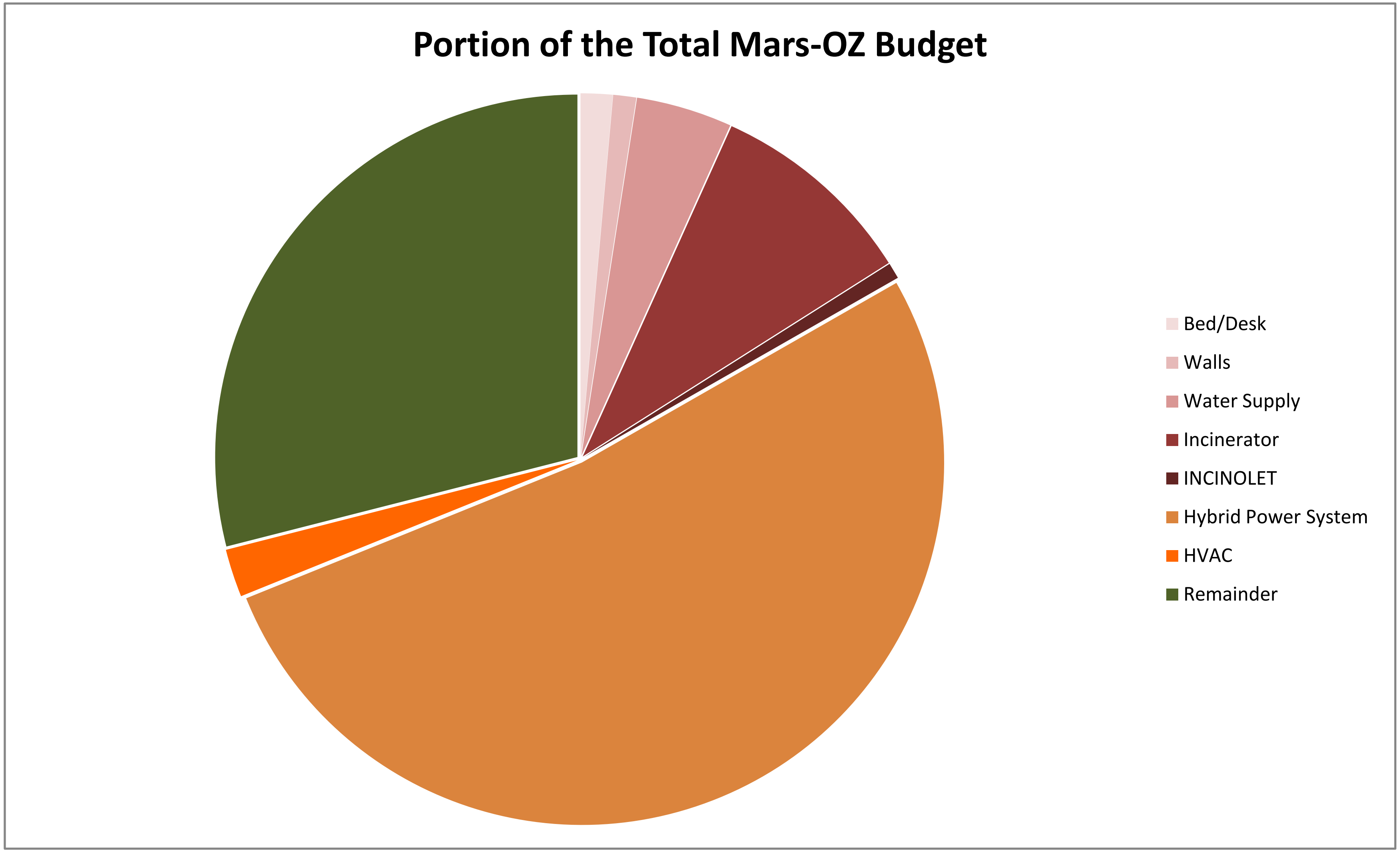

Figure 41: Portion of MARSOZ Habitat Budget Utilised by Martian Designs' Solutions

9. Design Philosophy

9.1. Our Philosophy: A System's Approach

Throughout the project Martian Designs followed many of the procedures of the NASA Systems Engineering Handbook[5]. This method helped the team approach the project in an organised and comprehensive manner. The team found the approach a manageable way of settings targets and dividing tasks. Managing the project through a group of set deliverables enabled simple tracking of the project's progress to ensure the group was on-target at all times.

There are particular sections of the systems approach that we have chosen to adopt:

Section 2.0 – Fundamentals of Systems Engineering:

This section presents a general guide to the general procedure followed in a systems engineering approach. This section helped Martian Designs management gauge the depth of the overall project and help on how to approach the project.

Section 3.0 – Program/Project Life Cycle:

Martian Designs followed the overall project life cycle program of this section. This section helped Martian Designs break the project into sections and create a set of deliverables with approximate due-dates for each part. This section acted as a guideline for what should be addressed in each of the deliverables which was the basis of each deliverable template.

Section 4.2 – Technical Requirements Definition:

This section outlines the transformation of stakeholder expectations into a definition of the problem. Martian Designs followed this procedure to convert the expectations of MARS-OZ into a complete set of technical requirements that must be validated. This ensured that client expectations were met to the desired level.

Section 4.3 – Logical Decomposition:

This step follows on from the technical requirements and involves the creation of detailed functional requirements for the system. Martian Designs used this section to help identify the "what" which must be achieved by the system at each level to ensure a successful project. Concepts used from this section include a Product Breakdown Structure and N^2 diagrams.

Section 4.4 – Design Solution Definition:

This section was used by Martian Designs to translate the high level requirements and functional requirements of the system into a design solution. Martian designs used this procedure to develop a number of alternate solutions detailed in the Preliminary Sketch Plan. The alternate solutions were then analysed through

[5] NASA Systems Engineering Handbook, http://education.ksc.nasa.gov/esmdspacegrant/Documents/NASA%20SP-2007-6105%20Rev%201%20Final%2031Dec2007.pdf

comprehensive trade studies which resulted in the choice of a preferred alternate solution. This preferred solution was then fully defined into a final design solution.

Section 5.2 – Product Integration:

This section focuses on ensuring that the products within the system integrate properly. Martian Designs followed the ‘bottom-up’ approach to ensure that products integrated within their sub-systems, and then the sub-system within the system as a whole. Particular emphasis was placed on system interfaces.

Section 5.3 – Product Verification:

This section was crucial to this document and to the end of project. Product Verification outlines the various types of verification available and how a particular part of the design solution must be verified. Martian Designs utilised this section as an outline for verifying that our final design solution has met all required criteria and if not, how and why it has not met a particular criteria.

Section 5.4 – Product Validation:

Product Validation is closely linked to Product Verification, however, it involves the confirmation that the end product will do what the customer required within the environment of use. This section can be, and was, performed simultaneously with product verification through the process of verifying the system within its environment of use.

Section 6.4 – Technical Risk Management:

Martian Design’s Risk Assessment Officer, Emily Carrie, used this section as a guideline for conducting risk assessments at various stages of the project. In particular, the Figure 6.4-1 – Technical Risk Management Process was used as a basis for identifying and mitigating risks. Figure 6.4 – 7, Risk Matrix, was used as a basis for determining the level of risk associated with a particular risk.

Section 6.5 – Configuration Management:

This section was used to ensure that configuration of the system was known and recorded and the impacts of any chance of configuration. This section was used to ensure that any changes in the future do not have detrimental impacts on the overall system and that any changes that do occur are successfully managed.

10. Risk Analysis

A risk analysis has been performed for the final design solutions recommended by Martian Designs. Each risk identified has been given an impact score based on the likelihood of occurring and the consequences. Mitigation strategies have been suggested and implemented in order to decrease the risk score.

Table 17 summarises the identified risks and the mitigation strategies implemented. All risks have been mitigated to a low impact score.

Table 17: Risk Analysis

Risk	Consequence/Impact	Risk Score	Mitigation	New Risk Score
General				
Fire	• Damage to experiments and facility. • Injury or death.	E	• Fire resistant wire housing, chemical storage and interior design. • Fire fighting equipment (chemical extinguisher, blankets, etc.). • Alarm system.	L
Distilled water supply runs out	• Inability to perform experiments.	M	• Large store of distilled water or ability to manufacture it	L
Failure of subsystems to be interoperable/compatible.	• Potential loss of system functionality.	H	• Good communication between teams especially with regard to interfacing issues.	L
Failure of subsystems to be compatible with existing design.	• Project failure	H	• Good communication with client and thorough knowledge of existing documentation to ensure all compatibility issues are identified and resolved.	L
Dust build-up in habitat	• Discomfort to occupants. • Possible impact on experiments.	M	• Supply adequate cleaning equipment. • Have clean entry procedures for entering and exiting lab.	L

Installation volunteers underqualified	• Possible damage to equipment and habitat. • Danger to volunteers	H	• Volunteers must have adequate training and experience for tasks they undertake. • Insurance should be taken out for the case of installation failure.	L
Subsystem - Waste				
Incinerator has hot surfaces	• Burns and scolding.	E	• Warning signs warn of danger. • Physical barriers to prevent contact. • Flammable materials are removed. • Additional insulation is required.	L
Accidental/Inadvertent smoke release	• Create an asphyxiating environment; death. • Render persons in cargo-bay unconscious, incapacitated.	E	• Provide continuous atmospheric monitoring and alarm system. • Automatic ventilation to revitalise air.	L
Incinerator System Breakdown	• Unprocessed waste builds up.	M	• Overflow storage is provided.	L
Incinerator operates @ 1000°C	• Aluminium rapidly weakens at 300°C; structural integrity could be affected. Aluminium fires are intense, spread rapidly, and are virtually un-extinguishable.	E	• Insulation is provided, protect fuselage. • Restraint and footing uses furnace steel types. • Incineration could be relocated outside the cargo bay (using the Cycloburn model). • Fire rescue and evacuation plan is produced and rehearsed regularly. • Reconsider aluminium construction. • At least consider using high-spec high-temp resist aluminium alloy (Dural).	L
Operator hazard from Waste	• Waste may contain sharp items (syringes) or biohazard waste.	H	• Waste disposed of in tear resistant HDPE medical waste bag. • Gloves, coverall and eye protection provided. • Limit access to cargo bay to authorised personnel only.	L
Electrocution Risk	• Electrical equipment in metal constructed cargo-bay with wet waste types creates hazard.	E	• Electrical system provides circuit breakers. • Equipment conforms with AS3000. • Fire extinguishers dry chemical type.	L

Workplace Used as Bedroom	• The cargo bay constitutes a 'workplace'. Using this a temporary sleeping quarter is risk for occupants, and contrary to OH&S guidelines.	E	• Incinerator is physically disabled from operation. • The incinerator door is physically restrained from opening (padlock). • Waste is stored in the incinerator but not processed until normal intensity duty is resumed. • Physical demarcation between dangers are enacted during this period	L
Ventilation System Failure	• Fire, smoke: Ventilation fails to automatically switch 'on', operator incapacitated; death	E	• Turnout-gear provided to effect rescue within asphyxiating environment.	L
Air-Intake & Exhaust Blockage	• The air-intake or flue system could be blocked or occluded causing insufficient air or smoke backflow	E	• Incinerator system requires employs a pressure sensor to detect occlusion. • Auto shutdown the incinerator. • Regular cleaning and inspection.	L
Alarm System Failure	• The Fixed fire alarm fails to sound; operator incapacitated; death	E	• The alarm system is cleaned regularly • Alarm system is checked regularly • Personal alarm (CO monitor) is carried as a backup system for the	L
Risk to Persons in Habitat Section	• Smoke and fire in cargo poses a risk to persons in Hab, fire spreads; death	E	• In event of fire, 'mission simulation' terminates and fire response enacted • Everybody evacuates; except fire rescue personnel	L
Diesel Flammability	• Hazard from flammable liquid, fire, smoke, asphyxiation	E	• Secured under-floor. Padlocked cage. • Monitored with CO sensor • 20L tanks limit maximum spillage. • Fire-extinguisher comply with fire type for diesel	L
Inability to cope with required waste quantity (possibly due to changing customer requirements)	• Failure of system to be effective for required purposes.	M	• Design with the possibility of extending the scale.	L
Inability to cope with required waste type (possibly due to changing customer requirement)	• Failure of system to be effective for required purposes.	M	• Design with possible flexibility in system if required.	L
Smoke and odour are released into the toilet room	• Health risk to inhabitants	M	• Ventilation fan installed in room.	L

System theoretically operational but cannot be practically implemented and maintained.	• System does not operate as planned and leads to waste build-up, unpleasant odour and excessive maintenance.	H	• Consider systems which have already been implemented in similar situations and proven to work practically.	L
Both toilets fail simultaneously and cannot be repaired instantly.	• With no toilets available inhabitants would have to break simulation to go to the toilet outside.	M	• Regular inspections of toilets to ensure faults are identified early.	L
Run out of bowl liners for toilet.	• Toilet cannot be used.	M	• Keep adequate number in storage. When supplies dwindle, ensure that more are ordered.	L
Toilet area becomes contaminated with pathogens due to spillage or leakage.	• Danger to inhabitants' health.	M	• Clean up spills and leakages as soon as possible using antibacterial cleaning products.	L
Toilet is improperly used.	• Possible damage to toilet and contamination to habitat.	M	• Ensure that all crew members and visitors are trained in proper use. Signage instructions are displayed.	L
Subsystem - Water				
Water quality fails to meet required quality standards.	• Danger to inhabitants. • Legal impact. • Impact on team reputation.	H	• Warn customer that system needs to be professional tested for quality standards.	L
Leak in water recycling system	• Loss of potable water. • Possible water damage in the area of the system.	M	• Ensure materials are designed for life-time of system or are replaced periodically. • Ensure joints are strongly fastened to reduce risk of leakage.	L
Water supply insufficient	• Experiment interruption. • Habitat evacuation. • Occupant discomfort. • Death.	H	• Overestimation of supply. • Availability of refills at base station.	L
Stored grey water festers	• Illness. • Loss of supply due to removal of water from system.	M	• Use appropriate grey water treatment. • Have quality detection system. • Ensure there is appropriate water circulation.	L
Storage container contaminates water	• Illness. • Major works on tanks. • Loss of supply due to removal of water from system.	H	• Selection of tank materials and lifetime analysis. • Have quality detection system.	L

Component Breakdown	• Water system stoppage. • Possible loss of water.	M	• Regular maintenance. • Ensure availability of spare parts. • Provision for non-powered water access.	L
Subsystem - Architecture				
Containment of chemicals and samples fails	• Health risks. • Experimental failure.	H	• Keep lab pressurized • Have sealable storage	L
Contamination of laboratory and samples	• Experimental failure.	M	• Keep lab pressurized • Have sealable storage • Make sure correct procedures are followed	L
Waste build up	• Environmental damage. • Bad Odour.	M	• Take waste that cannot be disposed of by facility offsite	L
Psychological damage to habitat occupants	• Difficulty working with one-another, depression	M	• Incorporate psychological considerations into habitat design	L
Structural failure of internal fittings	• Damage to property. • Injury to occupants.	M	• Redundancies in mounting hardware	L
Damage to habitat while unoccupied (weather, wildlife, vandalism, etc.)	• Repair costs. • Facility downtime.	M	• Sturdy outside locking mechanisms	L
Failure of soundproofing in bedrooms	• Discomfort to occupants.	M	• Soundproofing easily replaceable	L
Bed/desk system topples over	• Injury to crew member • Damage to habitat	H	• Lowering the clearance of the bed above the floor. • Widening the supports of the system to lower the centre of gravity. • Possibly bolt the system to the floor.	L
Bed/desk system joints fail	• Becomes impossible to convert between bed and desk. • Possible injury to inhabitants	M	• Ensure joints are lubricated and tested. • Keep spare joints on hand to replace faulty ones. • Desk restricted to minimum elevation of 700mm so it cannot fall on a sleeping occupant.	L
Wall collapse	• Injury to inhabitant • Damage to habitat.	M	• Panels are designed to be interlocked. • Chosen materials are sturdy.	L
Toxic gas emitted from soundproofing material over time	• Health risk to inhabitants	H	• Material chosen for soundproofing is checked to meet regulations for use in a confined environment. •	L

Subsystem - Power				
Power Failure	• Entire system failure. • Danger to crew. • Loss of research data.	H	• Provide a backup generator for emergency use	L
Extreme weather conditions (e.g. very high heat, severe storms)	• Damage to base. • Danger to crew.	H	• Ensure good climate control • Waterproofing of all external systems.	L
Transport damage	• Damage to base contents. • Drop in value of experiments.	H	• Ensure all equipment is properly stored for transport • Use robust equipment wherever possible	L
Lightning Strike	• Damage to electrical equipment.	M	• Lightning rods • Surge protection.	L
Failure of Air conditioning system	• Damage to heat-sensitive equipment. • Health risks for crew (e.g. dehydration, heat stroke)	H	• Provide backup fans	L
Power overload	• Possible fire. • Damage to equipment and experiments.	H	• Battery system to maintain power to critical areas	L
Underproduction of power	• System inadequate for customer needs.	H	• Ensure all power uses are considered (communication with client and other sub-teams) • Check all power calculations. • Include a safety net in production (provide more than is required) • Allow for possible extension if power needs increase significantly.	L
Incorrect output voltage of power supply	• Power unusable. • Possible damage to equipment.	H	• Ensure correct power supply design.	L
Build-up of dust on solar panels	• Reduced efficiency. • Insufficient power supply.	H	• Include cleaning as part of base routine.	L
Electrocution during maintenance of electrical systems	• Injury and possible death.	H	• Ensure components can be isolated for maintenance.	L
Diesel freezes	• Cannot run generator. Power supply inadequate.	M	• Store enough diesel for each mission. • Ensure cold weather diesel is supplied for winter missions.	L

11. Performance Analysis

Overall Martian Designs have performed well throughout this project. The performance of the project team is based around the following factors:

- Designs meet specified requirements
- Meeting the project timeline
- Meeting the project budget
- Producing quality, useable solutions

The final designs that the project teams have produced meet almost all relevant specified requirements. The design verification sections within this report outline how these specifications have been met.

Martian Designs are due to meet the final deliverable deadlines. The project has remained on track throughout the duration of the timeline, with only minor time extensions on some difficult deadlines.

Martian Designs have adhered to the project budget. The allowed times for each task were underestimated in some places and overestimated in others but as with all projects, adjustments were made to come in on time and meet the budget.

Perhaps the most important aspect of performance analysis is ensuring that the designs produced will actually be used when the MARSOZ Habitat is constructed. The design solutions that Martian Designs have presented are of a very high quality, and the client's level of satisfaction and interest would indicate that these designs will likely be utilised when the Habitat is constructed.

Based on the above factors, it can be surmised that the Martian Designs project team has performed to a high level throughout the duration of the MARSOZ Habitat design project.

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Relevant Standards

AS 1318-1985 SAA Industrial Safety Colour Code, Australian Standards

AS 1319-1994 Safety Signs for the Occupational Environment, Australian Standards

AS 1375-1985 SAA Industrial Fuel-Fired Appliance Code, Australian Standard

AS 1470-1986 Health and Safety at Work-Principles and Practices, Australian Standards

AS 1603 Automatic Fire Detection and Alarm Systems, Australian Standards

AS 1657-1992 Fixed Platforms, Walkways, Stairways and Ladders- Design, Construction and Installation, Australian Standard

AS 1668.1-1998 The Use Of Ventilation and Air-conditioning in Buildings, Australian Standard

AS/NZS 3000-2007 Wiring Rules, Australian Standards

AS4020/NZS4020 Products for Contact with Drinking Water

13. Appendix I: Architecture Specifications

Table 18: Specifications relevant to the overall layout of the sleeping cabin area taken from the Mars Society Australia's documentation.

Document	Page #	Client Spec. #	Client Specification	Performance Criterion	Additional Comments
MS-1	6	1	8 individual bedroom compartments	Cabin layout to provide a total of 8 individual bedroom compartments which are reconfigurable	
MS-1	22	2	Reconfigurable bedroom compartments	Simple reconfiguration from single room to double room	
MS-4	285	3	Reconfigurable bedroom compartments	Simple reconfiguration from single rooms to one large room	
MS-4	285	4	Rapid Reconfiguration	Minimise the amount of time it takes to reconfigure the bedrooms	
MS-1	22	5	Main lights	1 per room	
MS-1	22	6	Reading lights	1 per room	
MS-1	22	7	LAN ports	1 per room	
MS-1	22	8	Power supply	Power for supply each room	
MS-1	22	9	Stowage	Appropriate crew member stowage for each room	
MS-1	23	10	Fire/smoke detectors	1 per room	
MS-1	23	11	Fire extinguishers	1 per room	
MS-2	23	12	Portholes	1 per room	
MS-4	290	13	Noise	Meet statutory requirements for noise.	
MS-4	290	14	Temperature	Meet statutory requirements for temperature.	
MS-4	290	15	Ventilation	Meet statutory requirements for ventilation.	

MS-1	**6**	**16**	Provide Soundproofing	Minimal sound transference and adequate soundproofing between cabins.	
MS-1	**6**	**17**	Provide privacy	Adequate privacy between cabins.	
MS-4	**290**	**18**	Ventilation	Meet statutory requirements for ventilation.	
MS-4	**286**	**19**	Psychological effects	Design to mitigate the psychological effects.	

Table 19: Interpretation of MARS-OZ Specifications as Performed by Martian Designs for the Overall Sleeping Cabin System

Document	Page #	Team Spec. #	Team Specification	Performance Criterion	Additional Comments
MD-1	**8**	**1**	Reconfigurable design	Bedroom wall design will allow reconfiguration form single rooms, to double rooms to one open space.	
MD-1	**8**	**2**	Collapsible structure	Design will be able to be broken down for storage.	
MD-1	**8**	**3**	Storage	Collapsible design will store easily on and off research station.	
MD-1	**8**	**4**	Sound Insulation	Minimal sound transference and adequate soundproofing between cabins.	
MD-1	**8**	**5**	Injury Prevention	The system will minimise risk to the users.	
MD-1	**9**	**6**	Tour Capability	The system will minimise risk to the users.	
MD-1	**9**	**7**	Psychological upkeep	System will provide privacy and be reconfigurable.	
MD-1	**16**	**8**	sustainable and/or recyclable materials if possible	The design should utilise sustainable and/or recyclable materials and products if possible.	
MD-1	**16**	**9**	Very low environmental impact	All facets from manufacture to use to disposal of material should have minimum environmental impact.	

MD-1	**16**	**10**	'Idiot proof' design	The design should be made to accommodate student groups.	
MD-3	**Slide 5**	**11**	Maximise space effectiveness	The designs should be able to utilise space effectiveness,	e.g. collapsible foldable, storable, etc.

Table 20: Hierarchy of Functional Requirements of the Overall Sleeping Cabin Area and Constraints on its Design

Specification	Client spec. #	Team spec. #	Required Performance	Verification method	Additional Comments
4. Bedroom Layout					
4.1 Reconfigure					
4.1.1 Any number of rooms up to 8	**1**	**1**	Possible.	VD	It is expected that the design will allow set-up and pack-up by a single person.
4.1.2 To a single open space	**3**	**1**	Possible.	VD	See comment for specification 1.4.1.
4.1.3 Between a single room and a double	**2**	**1**	Possible.	VD	See comment for specification 1.4.1.
4.1.4 Quickly during a mission	**4**	**1**	Minimise seconds for 1 person	VT, VD	See comment for specification 1.4.1.
4.1.5 Between missions	**4**	**1**	Minimise seconds for 1 person	VT, VD	See comment for specification 1.4.1.
4.2 Provide Privacy					
4.2.1 Reduce Sound transmission	**16**	**4**	Minimise	VD & VT	
4.2.1 Prevent light ingress/egress	**17**	**7**	Minimise	VD & VT	
4.3 Mobility					
4.3.1 Within cabin	**N/A**	**N/A**	Maximise ease	VT, VD	
4.3.2 In/out of cabin	**N/A**	**N/A**	Maximise ease	VT, VD	
4.4 Storage Space					

4.4.1 General storage space	**9**	**N/A**	Maximise space (m^2)	VP, VT, VD	
4.4.2 Cabin (individual crew member)	**9**	**N/A**	Maximise space (m^2)	VP, VT, VD	
4.5 Human Factors					
4.5.1 Acoustics	**16&13**	**4**	Minimise	VT &VD	
4.5.2 Feelings of confinement	**19**	**7**	Minimise	VT	Associated with reconfiguration, room layout, e.g. portholes.
4.5.3 Provide ventilation	**18**	**N/A**	Maximise	VT & VD	AS 1668.2-1991 specifies standards for mechanical ventilation for acceptable indoor-air quality. AC/h = air changes per hour.
4.7.2 Temperature	**14**	**N/A**	Achieve comfort	VT, VD	
4.6 Room Fit out / Equipment					
4.61 Main lights	**5**	**N/A**	1 per room	Yes/No	
4.6.2 Reading lights	**6**	**N/A**	1 per room	Yes/No	
4.6.3 LAN ports	**7**	**N/A**	1 per room	Yes/No	
4.6.4 Power supply	**8**	**N/A**	1 dual power outlet per room	Yes/No	
4.6.6 Fire/smoke detectors	**10**	**N/A**	1 per room	Yes/No	
4.6.7 Fire extinguishers	**11**	**N/A**	1 per room	Yes/No	
4.6.8 Portholes	**12**	**N/A**	1 per room	Yes/No	

14. Appendix II: Architectural Design Verification

The following table conceptually determines whether the proposed design will meet the requirements of MARS-OZ.

Table 21: Inter-Cabin Wall System Specifications and Verifications

Specification/Constraint	Required Performance	Verification Method	Requirement Met	Actual Performance/Comments
1. Inter-cabin wall system				
1.1 Provide Privacy				
1.1.1 Reduce sound transmission	Minimise under 40dB(A)	VD & VT	Yes	It is anticipated that the system's soundproofing shall be adequate, however testing and demonstration will be required to confirm this.
1.1.1 Prevent light ingress/egress	Minimise (cd/m²)	VD & VT	Yes	Wall system is completely opaque.
1.2 Transport				
1.2.1 Within habitat	Maximise ease	VP, VT, VD	Yes	System components are small enough to manoeuvre within the habitat.
1.2.2 Into/out of habitat	Maximise ease	VP, VT, VD	Yes	System components are small enough that they can be moved through habitat entrances.
1.2.3 Externally	Maximise ease	VP, VT, VD	Yes	System components are small enough that many can be transported by utility vehicle in one trip.
1.3 Store				
1.3.1 Within module	Maximise ease	VP, VT, VD	Yes	System can be stored by constructing a wall immediately adjacent to an existing wall.
1.3.2 Externally	Maximise ease	VP, VT, VD	Yes	System can be disassembled and stored in spare space within the garage module, or offsite.
1.4 Reconfigure				
1.4.1 Any number of rooms up to 8	Possible, maximise ease, minimise seconds for 1 person	VT, VD	Yes	See section 4.3.3 for details.

1.4.2 To a single open space	Possible, maximise ease, minimise seconds for 1 person	VT, VD	Yes	All walls can be disassembled completely.
1.4.3 Between a single room and a double	Possible, maximise ease, minimise seconds for 1 person	VT, VD	Yes	Any single inter-cabin wall can be disassembled and removed leaving remaining walls intact.
1.4.4 Quickly during a mission	Minimise seconds for 1 person	VT, VD	Yes	Reconfiguration time for single to double room conversion is estimated at 20 minutes.
1.4.5 Between missions	Minimise seconds for 1 person	VT, VD	Yes	Between missions it is suggested that any unneeded system components be put into storage, preferably offsite.
1.5 Human Factors				
1.5.1 Minimise acoustics	Minimise under 40 dB(A)	VT &VD	Yes	It is anticipated that this requirement is met by the design due to the use of perforations in the wall system to allow better absorption of sound.
1.5.2 Minimise feelings of confinement	Minimise	VT	Yes	Walls are as thin as possible while meeting privacy requirements. This leaves as much space as possible remaining in each sleeping cabin. Rooms can be combined to give extra space if less than 8 crewmembers are inhabiting the facility.
1.5.3 Provide ventilation	AS 1668.2-1991 compliance (AC/h)	VT & VD	Yes	There will be enough clearance between cabin doors and the walls to permit ventilation.
1.6 Maintenance				
1.6.1 Frequency	Minimise MTTF and MTBR	VT	Yes	System needs no regular maintenance.
1.6.2 Ease	Maximise ease	VT	Yes	System requires no regular ongoing maintenance. Simple design allows for easy repair. Replacement parts are suggested to be stored in case of failure.
1.6.3 Cleaning	Minimise time (s)	VT	Yes	Only cleaning required is for exposed surfaces to be wiped down with disinfectant. Exposed surfaces are easy to wipe as they are primarily made from aluminium.
1.7 Materials				
1.7.1 To be selected from material list	Manufactured from wood aluminium	Yes/No	Partial	In addition to these, polyester has been used for the soundproofing, and steel has been used to provide

	and/or fibreglass			better structural rigidity to the design.
1.7.2 Fireproof / Fire retardant	NCC Sections C1, 2, 3 Compliance	VS & VT	Yes	The only non-metal component of the system is the soundproofing material that is listed as fire-resistant by the manufacturer.
1.7.3 Toxicity	Minimise units of Dermal LD_{50}	VS	Yes	No component of the system is toxic.
1.7.4 Allergenic	Hypoallergenic	VS	Yes	The only non-metallic material used is polyester, thus provided the system is kept reasonably clean there should be no issues.
1.8 Overall				
1.8.1 Non-load bearing	Non-load bearing	Yes/No	Yes	No proposed equipment to be used for fit out in rooms requires mounting to walls. Wall system shall not be used to support the roof. Care has been taken to ensure accidental contact between inhabitants and walls does not damage the system or pose a risk of damage to inhabitants.
1.8.2 No Sharp Corners	Zero sharp corners	Yes/No	Partial	Sharp corners have been minimised in the design; however some will still remain, in particular the hooks on the rails. Those that remain are in corners, where it is unlikely that an occupant will make contact with them. In addition they are usually partially covered by panels.
1.8.3 Low cost	Minimise cost ($)	VD & VS	Yes	Design can be manufactured with minimal skill and materials. A detailed cost estimate can be found in section 4.3.4.
1.8.4 Maximum safety	Maximise safety	VT & VD	Yes	Care has been taken to ensure the structure of the wall system is sound and unlikely to fail both under normal usage and in the event that an occupant falls against a wall.
2. Soundproofing Material				
2.1 Sound absorbing				
2.1.1 High sound absorption index	Maximise sound reduction index (R) over 50Hz to 5000Hz	VS, VT & VS	Partial	Sound absorption index is not provided by the manufacturer but seems likely to be suitable.
2.1.2 High vibration	Maximise damping	VS & VD	Partial	Vibration damping efficiency is not provided by the

damping efficiency	ratio (ζ)			manufacturer but seems likely to be suitable.
2.1.3 Wide sound absorbing frequency range	Maximise sound reduction index (R) over 50Hz to 5000Hz	VS, VT & VS	Yes	Sound reduction index is provided on the manufacturer's website and appears to be high.
2.2 Reliability				
2.2.1 Good structural sturdiness	Maximise	VS	Yes	System has few components all connected using sturdy mechanisms. Precautions have been taken to prevent system failure in the event that foreseeable loads are applied to it.
2.2.2 Impact resistance	Maximise	VS	Yes	Soundproofing is supported by aluminium panels and supporting rods at regular intervals. The actual soundproofing material is unlikely to be directly impacted against.
2.2.3 Humidity proof	Maximise	VS	Yes	Material is not a textile.
2.2.4 Dust proof	Maximise	VS	Yes	Material is smooth and can easily be wiped clean.
2.2.5 Resistant to microbes	Maximise	VS	Yes	Material is not a textile and can easily be wiped clean.

14.1.1. Design Verification

Table 22: Combined Bed-Desk Specification Verification

Specification/Constraint	Required Performance	Verification Method	Requirement Met	Actual Performance
2. Combined Bed/Desk System				
2.1 Cabin Furniture				
2.1.1 Provide Sleeping Furniture	Standard Australian single bed	VD	Yes	System includes a UK single bed.
2.1.2 Provide Study Furniture	Maximize for space	VD & VT	Yes	System includes a desk.
2.2 Reconfigure				
2.2.1 from Bed to Desk	Maximise ease	VT, VI, VD	Yes	Simple mechanism used.

2.2.2 From Desk to Bed	Maximise ease	VT, VI, VD	Yes	Simple mechanism used. Desk contents do not need to be removed (though care should be taken when reconfiguring).
2.3 Mobility				
2.3.1 Within cabin	Maximise ease	VT, VI, VD	Yes	System includes wheels for transportation and is relatively small when configured for use as a desk. Alternatively the system could be completely disassembled with relative ease.
2.3.2 Into/out of cabin	Maximise ease	VT, VI, VD	Partial	System can be partially disassembled.
2.4 Maintenance				
2.4.1 Ease	Maximise ease	VT	Yes	No regular maintenance of the system is required.
2.4.2 Cleaning	Minimise time (s)	VT	Yes	Metal surfaces are powder coated and can be wiped clean with disinfectant. Mattress and sheets can be removed for cleaning. Desk surfaces can also be wiped clean with disinfectant.
2.5 Store				
2.5.1 Externally	Maximise ease	VT, VI, VD	Yes	System folds up to be relatively compact.
2.6 Materials				
2.6.1 To be selected from material list	Manufactured from wood aluminium and/or fibreglass	Yes/No	Partial	System frame is made from steel for increased rigidity, desk is made from wood.
2.6.2 Fireproof / Fire retardant	NCC Sections C1,2,3 Compliance	VS & VT	Yes	Most of the system is non-flammable aside from the mattress.
2.6.3 Toxicity	Minimise units of Dermal LD_{50}	VS	Yes	No component of the system is toxic.
2.6.4 Allergenic	Hypoallergenic	VS	Yes	The only textiles used in the system are the mattress and the straps that secure it.
2.7 Design				
2.7.1 No Sharp Corners	Zero sharp corners	Yes/No	Partial	System contains no sharp corners, but care should be taken not to place body parts in such a way that they may get caught in the system's reconfiguration mechanisms.
2.7.2 Low cost	Minimise cost ($)	VD & VS	Yes	It is suggested that the system be custom

				manufactured so that it contains only essential components.
2.7.3 Maximum safety	Maximise safety	VT & VD	Yes	The system is sturdy, and contains few moving parts.

14.1.2. Design Verification

Table 23: Design Verification for Bedroom Layout

Specification	Required Performance	Verification Method	Requirement Met	Actual Performance
4. Bedroom Layout				
4.1 Reconfigure				
4.1.1 Any number of rooms up to 8	Possible	VD	Yes	Possible
4.1.2 To a single open space	Possible	VD	Yes	Possible
4.1.3 Between a single room and a double	Possible	VD	Yes	Possible
4.1.4 Quickly during a mission	Minimise seconds for 1 person	VT, VD	Yes	To be tested
4.1.5 Between missions	Minimise seconds for 1 person	VT, VD	Yes	To be tested
4.2 Provide Privacy				
4.2.1 Reduce Sound transmission	Minimise	VD & VT	Yes	All walls and doors are fitted with soundproofing and all cabins are sealable.
4.2.1 Prevent light ingress/egress	Minimise	VD & VT	Yes	All cabins are sealable.
4.3 Mobility				
4.3.1 Within cabin	Maximise ease	VT, VD	Yes	Design verified to maximise ease

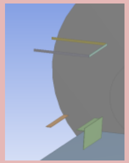
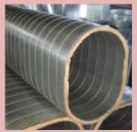
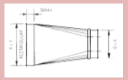
4.3.2 In/out of cabin	Maximise ease	VT, VD	Yes	Design verified to maximise ease
4.4 Storage Space				
4.4.1 General storage space	Maximise space (m^2)	VP, VT, VD	Yes	5.12m^2 floor space (plus emergency space)
4.4.2 Cabin (individual crew member)	Maximise space (m^2)	VP, VT, VD	Yes	1.42m^2 of floor space each cabin after fixtures subtracted.
4.5 Human Factors				
4.5.1 Acoustics	Minimise	VT &VD	Yes	All walls and doors are fitted with soundproofing and all cabins are sealable.
4.5.2 Feelings of confinement	Minimise	VT	Yes	Space maximised per cabin, one porthole per cabin, reconfigurable cabins.
4.5.3 Provide ventilation	Maximise	VT & VD	N/A	Outside of scope. For MARS-OZ to decide. Incorporation of vents into the cabins.
4.7.2 Temperature	Achieve comfort	VT, VD	N/A	Outside of scope. For MARS-OZ to decide. Incorporation of vents into the cabins.
4.6 Room Fit out / Equipment				
4.61 Main lights	1 per room	Yes/No	Yes	1 per room
4.6.2 Reading lights	1 per room	Yes/No	Yes	1 per room
4.6.3 LAN ports	1 per room	Yes/No	Yes	1 per room
4.6.4 Power supply	1 dual power outlet per room	Yes/No	Yes	1 dual power outlet per room
4.6.6 Fire/smoke detectors	1 per room	Yes/No	Yes	1 per room
4.6.7 Fire extinguishers	1 per room	Yes/No	Yes	1 per room
4.6.8 Portholes	1 per room	Yes/No	Yes	1 per room

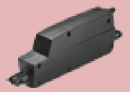
15. Appendix III: Waste Incineration System Components

Table 24: Off-the-shelf Waste Management System Components

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1. General Waste Management System					
1.1 Waste Collection and Storage System					
1.1.1 SULO SensaTouch® 20L Waste Receptacle		Hands-free opening, polypropylene trash receptacle. Designed for medical waste use. 3 colours (green, grey, & yellow). W: 270mm D: 370mm H: 420mm (+20mm lid)		6	$30.00
1.1.2 Medical Action Industries: Waste Bags		11 micron HDPE film medical waste bag (tear resistant). Caries hazard warning markings. 24 L capacity. Fischer Scientific #: 14-828-186	ASTM	1	$121.63 1000 bags
1.1.2 Scepter 20L Diesel Storage Cans		HDPE, resistant to expansion, no vent cap, childproof, internal spout W: 160mm D: 350mm H: 470mm Repco #: Scepter20L	AS2906	25	$27.99
1.1.3 Bunnings 50 L Storage Container		Heavy-duty polypropylene sealable container with handles. W: 570mm D: 470mm H: 290mm		1	$24.95
1.1.3 MasterLock Padlock		MasterLock Steel padlock, key opening, 3 per pack		1	$41.63
1.1.4 Storage Enclosure Facility (Self-Designed Self-Manufactured)		Self-manufactured storage facility. Aluminium construction, lockable. BOC Gas commercial product seen adjacent used for costing purposes.		1	$1600

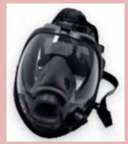
Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.2 Material Handling System					
1.2.1 Premium Red Butthide Gauntlet Glove		Kevlar® reinforced welders and foundry glove. Used in high heat applications. BOC Gas Part #: 743371	AS 2161	2	$26.60
1.2.2 Double Dipped PVC Gauntlet Glove		Heavy-duty double coated PVC glove for chemical protection fats grease, acids. (Not for heated applications) BOC Gas Part #: 743348	AS 2161	2	$9.68
1.2.3 Proban Coverall		Designed for Off-shore Oil & Gas and Bushland fire fighting. Uses flame retardant fabrics (Proban) for protection (88% cotton & 12% nylon). High-visibility standards	AS 4824 AS 1906	1	$135
1.2.4 Hard-hat with Visor		Lightweight versatile helmet for working professional. Ventilated shell, comfortable for all day use.	AS 8600	1	$84
1.3 Waste Incineration Unit					
1.1.1 MediBurn-20 Incinerator Unit		Fully self-contained, diesel-fired burners, primary and secondary chambers temperature controlled. Internal diesel tank. Incineration rate: 20kg/h Diesel: 0.55-1.0 L/kg waste Power: 0.35kW 220V AC (50Hz) W: 860mm, H: 2080mm D: 1570mm, Mass: 907 kg	ISO 9001 US EPA	1	$ 40000 +Handling

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.1.2 Furnace Restraint and Footing		Self-designed, self-manufactured. Heat resistant alloy Inconel-600 (Ni-Cr furnace steel; high strength, low conductivity, corrosion resistant)		1	$1500
1.1.3 FIBERTEX 820 Rockwool Insulation Blanket (Bradford)		Capable of exposure to 820°C. Used for ovens, boilers reactors, process equipment. Meet fire, corrosion, mechanic required. Thickness: 25mm	BS874-1973 AS 1530.3:1999 BS2972-1975 BS 3958.5- 1969	16m²	$36.75/m²
1.4 Electrical Subsystem					
1.2.1 ACE 3-Phase Power Converter AP2B		Rotary-type 3-phase generator Reconfigure to alter voltages, quiet W: 279mm, L: 305mm H: 400mm, Mass: 36 kg		1	($1000) TBC
1.5 Ventilation Subsystem					
1.5.1 Colt® W-Liberator Powered Ventilator (630mm fan-blade)		Smoke control and heat extractor system. Wall mounted louvered aperture. Aluminium constructed. 380V 3-phase 50 Hz, 0.75kW, 79dBA. Airflow: 2.6 m³/s	>100 AC/h max	1	($1000) TBC
1.5.2 Duraduct Oval Duct		Oval shaped thermally acoustically insulated ducting W: 533mm H: 203mm		5m	($300) TBC
1.5.2 Duraduct Reducer Fitting		Rectangle-to-Oval transform fitting. X=185mm Y=185mm A=533mm B: 203mm		1	($150) TBC

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.5.4 LINAK LA12 Linear Actuator		Linear actuator to control vent opening. Max thrust: 750N, Rate: 40mm/s		5	($50) TBC
1.5.5 LINAK CB14 Control Box		CB14 with microprocessor is needed to run up to five actuators. Translates signals from control unit into controlled movement. 230V AC 50Hz		1	($350) TBC
1.6 Safety Monitoring and Alert Subsystem					
1.3.2 Scott® Proton ZM CO Gas Detector		Personal CO gas monitoring sensor, to be worn on belt. Provide backup should the cargo fixed system sensor fail. No Calibration required Fisher Safety #: 19-049-9729		1	$178.00
1.6.1 Scott® Sentinel-II 7200 (Fixed Gas Sensor- Control Unit)		Control unit for fixed chemical sensor; receives two channels of chemical sensor input, can actuate alarms and ventilation. Has inbuilt alarm 85 dB. UPS by battery. 3-pin power plug in. Wall mounted unit. 240V 50 Hz AC, using max 150 W W: 2200mm H: 229mm D: 137mm	UL and CSA approvals	1	($500) TBC
1.6.2 Scott® Fixed Gas Sensor		Gas detection sensors		2	($80) TBC
1.6.3 Tyco Vigilant F3200-8 Zone Fire Indicator Panel		Control panel for 8 alarm zones, receives detector signal. UPS by battery. 240V 50Hz, 150 W W: 550mm H: 440mm D: 230mm	AS 4428	1	$1100

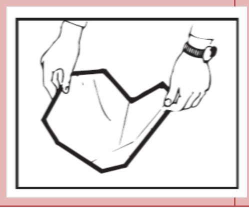
Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.6.4 Tyco T-Gen50 Tone Generator		Generates Alert and Evacuate voice messages in line with standards. W: 483 mm H: 45 mm D: 50mm; 50W @ 20V DC	AS 2220 ISO 8201	1	$700
1.6.5 Tyco 614CH Heat and CO detector		Responds quickly to fires by dual CO and heat detection. Fewer false alarms.		2	$100
1.6.6 Tyco 5B Universal Base		Required for attaching Type 614 detectors to wall/roof		2	$15
1.6.7 Tyco SU0600 Manual Call Point		Manual Call Point (MCP) for crew remote alarm triggering	AS 1670	1	$30
1.6.8 Tyco 'One Shot' EA005 Speaker		Generates 92 dB @ 1m. 140mm diameter for 10-13mm ceiling 5W PA speaker over 100Hz-15kHz	AS 2220	1	$20
1.6.9 Tyco EA0302 Strobe		Rapidly grab attention by visual means. 24 V DC 80mA		1	$50
1.7 Safety Equipment Subsystem					

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.7.1 Heat Guard 430FB Fire Blanket		Fire retardant, economical, lightweight, long-life, Australian standard compliance 1.8 ×1.2 m blanket with wall bag BOC Gas Part #: FB1812W	BS 476 Part: 7 UL 214	2	$31.69
1.7.2 FlameGuard® ABE Dry Chemical Powder		Dry chemical powder extinguisher for flammable liquids, wood, paper and live electrical equipment. 9 kg variant BOC Gas Part #: 2060/17	AS 1841.5	2	$183.75
1.7.3 Heavy Duty Extinguisher Bracket		Fire extinguisher restraint device 9kg device variant BOC Gas Part #: 70076		2	$5.85
1.7.4 Total Fire Group Fire Fighting Turn Out Gear		Lightweight protective clothing for fire fighting; Thermal resistance by Nomex and Mechanical strength from Kevlar, vis by 3M Scotchlite Fisher Safety #: NC9667771 Fisher Safety #: NC9667772	US MilStd	1	$4823.26
1.7.5 Bullard Firedome FXA-1 Helmet (Red)		High-temp resistant thermoplastic fibreglass, fracture resistant, 3M Scotchlite visibility SCBA integrate Fisher Safety #: 19-822-177	AS 4067-2004	1	$430.00

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.7.6 Scott® Vision 3 Face Mask		Suits the complete Scott Safety range of SCBA, Increased vision, scratch resistant, silicon face seal. Available from Wormald.	AS 1716-2003	1	$408.50
1.7.7 Fire-Dex H37 Hood		Nomex and Lenzing fibres for heat and flame protection. Fisher Safety #: 19-037-154A	NFPA 1971		$67.55
1.7.8 Scott® Sigma 2 Self-Contained Breathing Apparatus		SBCA for lowest cost and highest performance. Designed for shipboard (marine) and confined space fire fighting. Available from Wormald	SOLAS	1	$1000
1.7.9 Honeywell Ranger® Structural Pull-On Bunker Boots		Meets fire fighting boot standards, heat, fire, waterproof and chemical resistant. Steel insert crush protection. Fischer Safety #: 19-051-734	NFPA	1	$395.87
1.7.10 Shelby Proximity Gear Glove		Higher rating than structural gear. Multilayered glove Nomex and Kevlar. Cut and heat resistant while maintaining high dexterity Fisher Safety #: 19-100-343	NFPA	1	$220
1.7.11 Streamlight Survivor LED Right Angle Torch		Shockproof, rechargeable NiCad battery, heavy-duty. 4 hrs of continuous illumination Fisher Safety #: 19-165-616	NFPA 1901 NFPA 2003	1	$241.52
1.8 Workplace Integration					

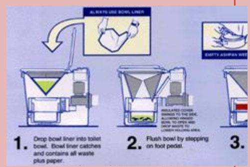
Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.8.1 Workplace Wall Mount 5 First Aid Kit		Fully stocked wall mounted first aid kit for high-risk environment. W: 460mm H: 730mm D: 155mm BOC Gas Part #: 856629	SA Govt Compliant Kit	1	$401.00
1.8.2 Emergency Eye Station		Emergency first aid for eye injuries W: 260mm H: 170mm D: 80mm BOC Gas Part #: 856592	OHS Compliant	1	$55.00
1.8.3 Burns Station Kit		Emergency first aid for burns W: 250mmH: 185mmD: 90mm BOC Gas Part #: 856591	OHS Compliant	1	$99.00
1.8.4 Mandatory Signs: **1. Eye Protection** **2. Helmet** **3. Footwear** **4. Personal Protective Clothing**	 	Mandatory signs must be placed visible upon entry into the room and within the room. Metal construction W: 225mm H: 300mm BOC Gas Part #: 103 BOC Gas Part #: 106 BOC Gas Part #: 111 BOC Gas Part #: 112 BOC Gas Part #: 113	AS 1319	5	$21.29
1.8.5 Prohibition Signage	 	BOC Part #: 401 BOC Part #: 405	AS 1319	2	$21.29
1.8.6 First Aid Signage	 	Placed above first aid station container. Metal construction W: 180mm H: 250mm BOC Gas Part #: 502 BOC Gas Part #: 506	AS 1319	2	$21.29

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.8.7 Danger Signage		Danger Signs on entry and within the cargo bay. Keep hands clear sign on incinerator. BOC Gas Part #: 203 BOC Gas Part #: 206	AS 1319	3	$21.29
1.8.8 Floor Signage		Floor sign to be placed about incinerator Vinyl; Diameter: 400 mm BOC Gas Part #: FG1116	AS 1319	2	$21.29
1.9 System Cleaning					
1.9.1 Dura Fresh Scouring Pads		Scouring Pads and wiping for cleaning bins and surfaces		1	$2.85
1.9.2 Fisher brand Ultrasonic Cleaning Solution (3.8L)		Heavy duty, high performance laboratory cleaning solution. Long lasting, biodegradable. Non-toxic and odourless, ammonia-free and non-flammable with no acid, caustic. Bottle: 3.8L; Dilute 10x Fisher Safety #: 15-335-80		2	$74.19
1.9.3 Dustbuster Handheld Vacuum Cleaner		Wall-mounted cyclonic handheld vacuum cleaner (9.6 V, 16 W) For readily accessible cleaning of workplace		1	$89.00

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
1.9.4 Rubbermaid Brute Mop Bucket and Wringer		Mop, bucket (33 L) and wringer W: 420mm D: 390mm H: 420mm Fisher Safety #: 19-050-647	Fits in larger storage compartment	1	$88.70
1.9.5 Ash Collection Container and Small Shovel/Scoop and Wire Cleaning Brush		Self-design and manufactured from aluminium sheet. Sealable. Small shovel fits neatly within. Unit fits neatly into smaller storage section W: 350mm H: 250mm D: 300mm		1	$100
1.9.6 Mobile Wet Floor Signage		Safety signage must be posted when cleaning is in progress 60mm high wet floor signage BOC Gas Part #: LCA26819	AS 1319	1	$40.28
2. Human Waste Management System					
2.1 Waste Collection System					
2.1.1 TR Model INCINOLET Electric Incinerating Toilet®		Incinerating toilet system for processing of human waste. To be installed in toilet rooms in habitat.		2	$1849 USD TBC
2.1.2 INCINOLET Bowl Liners		Specially designed bowl liners for use in the INCINOLET toilet. Box is of 200 folded liners.		20	$18 USD TBC

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
2.1.3 INCINOLET Bowl Liner Dispenser		Wall-mounted dispenser for bowl liners.		2	$14.95 USD TBC
2.1.4 INCINOLET Installation Kit (240V)		Kit includes 18" PVC pipe, an elbow, rubber coupling, and 240 volt wall receptacle to match 240 volt plug on toilet.		2	$19.95 USD TBC
2.2 Ventilation and Fire Safety System					
2.2.1 Standard Dryer Flap		Dryer flap for connection to external end of PVC ventilation pipe to prevent back-drafts.		2	$7
2.2.2 Standard PVC Elbow		PVC elbow for connection to external end of PVC ventilation pipe to prevent back-drafts.		2	$1

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
2.2.3 Standard Ventilation Fan		Ventilation fan for odour or smoke in toilet room.		2	$83
2.2.4 Standard Smoke Detector		9V Photoelectric Smoke Alarm.		2	$17.90
2.2.5 FlameGuard® ABE Dry Chemical Powder		Dry chemical powder extinguisher for flammable liquids, wood, paper and live electrical equipment. 9 kg variant BOC Gas Part #: 2060/17	AS 1841.5	1	$183.75
2.3 Cleaning and Maintenance System					
2.3.1 Dustbuster Handheld Vacuum Cleaner		Wall-mounted cyclonic handheld vacuum cleaner (9.6 V, 16 W) For readily accessible cleaning of workplace		1	$89.00
2.3.2 Rubbermaid Brute Mop Bucket and Wringer		Mop, bucket (33 L) and wringer W: 420mm D: 390mm H: 420mm Fisher Safety #: 19-050-647	Fits in bathroom storage compartment	1	$88.70

Component PSP spec. #	Picture	Description	Performance	Quantity	Price
2.3.3 Formula 409 Cleaner/Degreaser		1 Gallon bottle for cleaning of the toilet.		1	$12.50
2.4 Workplace Integration System					
2.4.1 Required Processes Sign		Sign instructing inhabitants on proper use of the toilet.		2	TBC
2.4.2 Wet floor warning sign		Require on bathroom entrance door W: 180mm H: 250mm BOC Gas Part #: 311		2	$21.29

16. Appendix IV: Waste System Design Verification

Table 25: Design Usage Specification

Specification	Required Performance	Verification	Additional Comments
Concept Proving	The incinerator concept is simulated and tested on full-scale. Final design resolves any risk of fire from high temperature incineration.	VS VT	Incineration concept must be shown to be safe.
Materials Fire Rating	Any materials and systems placed in the cargo-bay by MARS-OZ are fire rated and heat resistant.	VI	Sensitive systems may be shielded with welders guard.
Trained Incineration Operator	Crewmember is trained in safe operation of incinerator.	VT	Testing examination and demonstration of skill required.
Fire Response Training	Crewmember is trained in response to fire, smoke and asphyxiating environments.	VT	Testing examination and demonstration of skill required
Authorised Access Only	MARS-OZ enacts system that physically restricts access to cargo-bay during incineration procedure.	VI	Cargo-bay door is lockable but readily accessible in emergency.
Lockout Feature	MARS-OZ enacts systems that physically restrict access to the incinerator.	VI	Incinerator door is restrained from access. Control system is locked out.
Crew Training	MARS-OZ enacts protocols to ensure that the hazardous environment created by the incinerator is duly respected.	VI	

Table 26: Design Verification

Specification	Required Performance	Design Performance	Verification	Additional Comments
1. General Waste Management System				
1.1 Waste Collection and Storage System				
Waste Collection	Waste Collection is provided	General, green and medical waste collection types are provided, sufficient volume.	Passed	
Waste Storage	Waste Storage is provided	50L of additional waste storage is provided.	Passed	Emphasis on immediate processing
Diesel Storage	Sufficient diesel storage to sustain continuous operation	10% excess provided solely for incineration.	Passed	Additional diesel if backup diesel generator not required
Secure Storage	The system can be locked	Lockable storage	Passed	
1.2 Material Handling System				
Waste compactor	A waste compactor is required	Waste compacter not provided	Failed	Emphasis on immediate processing not storage
Waste Segregation	Waste is sorted according to type	Multiple waste collection types provided.	Passed	
Materials Handling Safety	Means to safely transfer materials is provided	Protective clothing apparatus are provided.	Passed	
1.3 Waste Incineration Unit				
Incineration Disposal	Waste biological materials can be incinerated	Medical incinerator type	Passed	

Specification	Required Performance	Design Performance	Verification	Additional Comments
System Mass	Total much mass less than 4T	Total system mass < 1T	Passed	
Rapid Destruction	At a minimum the system achieves counterbalance	Waste incineration rate >> rate of generation (20 kg/h)	Passed	Ideally 5-10kg/h would be more suitable
Complete Destruction	Inorganic Remnants Only (Ash)	Mediburn-20 incineration yields only inert products	Passed	
Inert Gaseous Emissions	Meets or exceeds the EPA guidelines for solid waste incineration	Meets US EPA standards	Passed	
Multiple waste processing	Can simultaneously process varied wastes	Mediburn-20 can process multiple wastes	Passed	
Incompatibles Waste Eliminated	Only compatible waste are incinerated	Source separation, waste segregation provided	Passed	
Low power operation	Minimal electricity demand	0.35 kW; Primarily diesel	Passed	
Minimal Spatial Requirement	Occupies Minimal Volume	Poor.	Failed	
1.4 Electrical Subsystem				
Voltage requirement	Power drawn @ 240V or 12 V	Drawn at 240V	Passed	
1.5 Safety Subsystem				
Fire/Smoke Detectors	Compliance with Relevant Standard: AS1603 & AS1670	Included	Passed	
Heat Detectors	Compliance with Relevant Standard: AS 1603	Included	Passed	
Fire Extinguishers	Compliance with Relevant Standard: AS 1851	Included	Passed	
Gas masks and goggles	Compliance with Relevant Standard: AS 1716	Included	Passed	
Sprinkler system	Compliance with Relevant Standard: AS 2118	Not Provided	Failed	Additional fire extinguisher was considered more practical

Specification	Required Performance	Design Performance	Verification	Additional Comments
System Isolation	The system can be isolated	Storage isolated beneath floor Sealed by airlock	Passed	
Zero internal contamination	Design shall prevent internal contamination	Ventilation is provided	Passed	
1.6 Workplace Integration				
Insulation	Shall be by fibre glass	Fibermesh Rockwool 820	Passed	Materials are similar in nature
Structural supports	Shall be constructed of Aluminium	High-spec alloy specified	Failed	Support needs to be of heat resistant nature; furnace steel
Fire Resistance	Resist the conductive, convective and radiant load	Fibermesh Rockwool 820 duty under 820°C. Non-combustible	Passed	
Maintenance	Easily maintained by the crew	Required after every use. Used only every second day.	Passed	
Ventilation	Compliance with Relevant Standard: AS1668	Ventilation is provided; can surge to >100 AC/h	Passed	
Remote Control Functionality	Incineration unit can be operated remotely	FIP can remotely shutdown the incinerator	Passed	
System Invisibility (Odour)	Internal atmosphere odour levels in compliance with standard: AS 4323	Ventilation is provided	Passed	
System Invisibility (Noise)	Within the guidelines set out in the PSP for noise: AS 1269	Ducting provides acoustic insulation	Passed	
2. Human Waste Management System				
2.1 Waste Processing System				
Complete Destruction	Inorganic Remnants Only (Ash)	INCINOLET produces only inert ash.	Passed	
Performance of Processing	Toilet system can adequately process waste for the entire crew.	Each of the two toilets can service up to 8 people.	Passed	

Specification	Required Performance	Design Performance	Verification	Additional Comments
Backup System	If one toilet should fail, the other can adequately service the crew.	Each of the two toilets can service up to 8 people.	Passed	For a crew size of up to 8 people.
2.2 Power System				
Voltage Requirement	Power drawn @ 240V or 12 V	Drawn at 240V	Passed	
Power Requirement	Adequate power can be supplied.	1.5-2 kWh per use	Passed	Power system can supply this.
2.3 Ventilation and Fire Safety System				
Ventilation	Toilet and room are adequately ventilated.	Both the INCINOLET toilet and room are ventilated to the outside.	Passed.	Fan within the toilet with ventilation pipe. Exhaust fan installed in room.
Heat Detector in Toilet	Thermostat shuts off operation should temperatures become too high in the unit	Included	Passed.	
Fire/Smoke Detectors	Compliance with Relevant Standard: AS1603 & AS1670	Included	Passed	
Fire Extinguishers	Compliance with Relevant Standard: AS 1851	Included	Passed	
Evacuation Plan	Crew are aware of evacuation plan and it is displayed around the habitat.	Included	Passed	Evacuation plan provided by MARS-OZ.
2.4 Cleaning and Maintenance System				
Maintenance	Easily maintained by the crew	Ash pan checked regularly and emptied when required. Manual for other maintenance provided.	Passed	Basic maintenance is simple.
Cleaning	Cleaning is simple and sufficient so that crew are not exposed to pathogens.	Antibacterial surface cleaner used.	Passed.	Clean according to provided instructions with surface cleaner of choice.

Specification	Required Performance	Design Performance	Verification	Additional Comments
2.5 Workplace Integration System				
Signage	Adequate signage instructing proper use of the system is provided.	Included	Passed.	Signage made by MARS-OZ
System Invisibility (Odour)	Internal atmosphere odour levels in compliance with standard: AS 4323	Ventilation is provided	Passed	Details in ventilation section.
System Invisibility (Noise)	Within the guidelines set out in the PSP for noise: AS 1269	System operates with low noise.	Passed	According to manufacturer.

17. Appendix V: Water System Components

Water Processing Major Components

Table 27: Major Processing Components

Function	Description	Component Lifetime	Notes
Aqua Sun's Villager A1's Major Components			
2.1 5.0 Micron Sediment Pre-Filter [NFS Approval Rating]		1 Year	Non-washable.
2.1.1 Initial Filter	Removes ground water sediment down to 5 microns.		
2.1.2 Carbon block protector	Prevents carbon block filter from premature clogging.		
2.2 0.5 Micron Carbon Block [NFS Approval Rating]		1 Year approximation	Produces clean tasting water.
2.2.1 Parasite Removal	Removes and reduces giardia lamblia, cryptosporidium cysts, and other parasites.		
2.2.2 Microorganism Removal	Removes microorganisms down to 0.5 microns.		
2.2.3 Chemical removals	Removes volatile organic chemicals (VOCs), pesticides and herbicides and benzene.		
2.2.4 Improved water	Removes sediment, colour, bad taste and odours (e.g. hydrogen sulphide).		
2.3 UV Disinfection Lamp [NFS Approval Rating, Certificate of Analysis]		9000 hours approximately 3 years	No harmful side effects unlike some chemical treatments. Lamp Output: 16,000 microwatt seconds per centimetre squared
2.3.1 Removes bacteria & viruses	Removes bacteria and viruses up to 99.999% purity. Effectively removes microorganisms.		Removes e-coli, coli form, cholera, legionnaires' disease, hepatitis, typhoid fever, dysentery, infectious jaundice, influenza, enteric fever and others.
2.4 EDIS 'N' Electrodialysis Reversal Unit		7-10 years	50L/h

Function	Description	Component Lifetime	Notes
2.4.1 Pre-filtration treatment	Villager A1 provides the required filtration treatment for EDIS N		Chlorine should not be added till after EDIS processing output
2.4.2 Water Pump Grundfos NSB 5-33	EDR (EDIS N) requires between 1-3 bar of inlet pressure for operation. Electrical: 0.75kW 240 V 50 Hz AC single phase W: 275mm H: 205mm D: 160mm		@ Low flow-rate (50L/h) provides a maximum 31 m hydrostatic head (3 bar) Meets EN 66035 IP 55
2.4.3 Powerbox PUP 30-110	Variable voltage; Inverter-rectifier unit, (30-110W) (AC/DC); provide 150V DC current to EDIS N unit		AS/NZS CISPR11 Group 1 Class A
2.4.4 Electrodialysis Reversal: EDIS-N	Effective removal of nitrate, chloride, sulfate, fluoride, calcium and sodium cations and heavy metals; retentate is purified of these.		3g/L input total dissolved solids (TDS) reduced to 0.3 g/L TDS
2.4.5 Residue outlet	The electrolyte rich by-product (permeate) (10-20% of water) is segregated and disposed of appropriately		Dispose of permeate to sludge pond
2.5 Power			N/A
2.5.1 Internal Power-Supply	12V auxiliary power-supply.		
2.5.2 Voltage Transformer	Converts standard 240V power from solar-panels to 12V power for the device		
2.5.3 Lamp Out Circuit (Upgrade)	Additional solenoid valve shall cut-off the system if the UV light is not on.	See 2.4: Power	
2.6 Frame			In excess of 20 years
2.6.1 Frame	Powder coated, aluminium frame.		
2.7 Residual Chlorine			N/A
2.7.1 Chlorinator Injector System	Injects chlorine, when required, as a residual disinfectant in the potable water tank.		Chlorine should not be added till after EDIS processing output
2.8 Plumbing and Wiring			N/A
2.8.1 Plumbing	10-foot inlet female hose and 10-foot outlet male hose pre-plumbed into system.		
2.8.2 Wiring	System is pre-wired.		
2.9 Replacement Parts Kit			N/A

Function	Description	Component Lifetime	Notes
2.9.1 Parts	Consists of a Filter and UV replacement.		
2.10 Overall			N/A
2.10.1 Size	18" (45.7cm) long x 16" (40.6cm) wide x 7" (17.5cm) deep.		
2.10.3 Weight	Approximately 11.3kg.		
2.10.4 Mounting	Wall mounted.		
2.10.4 Water Input	System is able to pull water from water sources.		

Water Storage Major Components

Table 28: Water Management System Components

Component	Picture	Description	Performance
Water Storage System			
1 Water Storage tanks			
1.1 1350L Custom-designed water tank – top-up tank		Stores fresh water for the mission. Fibreglass shell, two in/outlets. Width: 800 mm Height: 1900 mm Length: 1140 mm	AS4020
1.2 1000L Custom-designed water tank – post-processing tank		Stores recycled grey water after processing. Fibreglass shell, three in/outlets. Width: 800 mm Height: 1900 mm Length: 850 mm	AS4020
1.3 500L Custom-designed water tank – pre-processing tank		Stores grey water before recycling. Fibreglass shell, three inlets/outlets. Width: 800 mm Height: 1900 mm Length: 425 mm	AS4020
1.4 200L Villager Buffering Tank			
2 Water monitoring system			
2.1 Water level meter		Aquameta AN420-5 pressure sensor. 4-20mA output	
2.2 Conductivity Meter		Royce Water Technologies LTH BC9 Series Electrodeless Conductivity Indicator	
2.3 Turbidity monitor		Royce Water Technologies Turbidity Sensor VisoTurb	

Component	Picture	Description	Performance
2.4 pH meter		QM1670 handheld pH meter Mass: 170g	
2.5 pH meter buffer solution refills		Buffer solution to fill QM1670 handheld pH meter	
2.6 Water flow meter		Measures flow rates of water throughout habitat Requires digital output, max. Flow rate to be determined through detailed design of the plumbing system.	
3 Refill Operations			
3.1 2400L Vehicle-borne Tray Water Tank		Mounts on utility vehicle tray for water transport. Two in/outlets.	AS4020
3.2 Water pump		Davey XF-92 240V, 50Hz power supply Allows pumping from ute water tank into habitat tank. Pumping rate of up to 90 L/min into tank. Powered through habitat power grid, mounted on ute	AS4020
3.3 Hose		Connects habitat water storage with external supply	AS4020

18. Appendix VI: Water System Design Verification

Water Storage Specifications

Table 29: Water Processing Specifications

Specification	Required Performance	Verification	Additional Comments
Water Processing System			
System Verification	The water storage system is tested, verifying quality of water output, sensor operation and process applicability.	VT	This need only show that materials are appropriate, and that water quality does not degrade severely over time
System Cleaning Processes	An appropriate cleaning process for the storage system must be designed and implemented	VT	
Process Training	At least one occupant of the habitat is knowledgeable in all system processes, allowing for on-site analysis of errors in the system	VT	
Detailed Component Selection	Further design work must be done on component selection, to result in a full and usable design.	VD, VSD	Incomplete components are flow meters, hose and ute-mounted water tank
Water Storage System			
System Verification	The water storage system is tested, verifying quality of water output, sensor operation and process applicability.	VT	This need only show that materials are appropriate, and that water quality does not degrade severely over time
System Cleaning Processes	An appropriate cleaning process for the storage system must be designed and implemented	VT	
Process Training	At least one occupant of the habitat is knowledgeable in all system processes, allowing for on-site analysis of errors in the system	VT	
Detailed Component Selection	Further design work must be done on component selection, to result in a full and usable design.	VD, VSD	Incomplete components are flow meters, hose and ute-mounted water tank

Design Verification

Water Processing Verification

Table 30: Water Processing Requirements Verification

Specification/ Constraint	Required Performance	Verification Method	Requirement Met	Actual Performance
1 Water System Processing				
1.1 Water Processing				
1.1.1 Water Quality Requirements				
Taste	Meets the relevant standard for taste	VSD	Yes	Manufacturer is an approved UN supplier and therefore meets WHO standards (Guidelines for Drinking Water Quality, Table 7.4 Chapter 7 p132)
Turbidity	Meets the relevant standard for turbidity	VSD	Yes	Manufacturer is an approved UN supplier and therefore meets WHO standards (Guidelines for Drinking Water Quality, Table 7.4 Chapter 7 p132)
Aesthetics	Meets the relevant standard for aesthetics	VSD	Yes	Manufacturer is an approved UN supplier and therefore meets WHO standards (Guidelines for Drinking Water Quality, Table 7.4 Chapter 7 p132)
Bacteria	Meets the relevant standard for bacteria content	VSD	Yes	Manufacturer is an approved UN supplier and therefore meets WHO standards (Guidelines for Drinking Water Quality, Table 7.4 Chapter 7 p132)
Sodium Level	Meets the relevant standard for sodium (<180mg/L) for AS taste threshold	VSD	Yes	National Water Quality Management Strategy; Australian Drinking Water Guidelines 6: 2004 NHMRC. (Based on EDIS N achievement of 300mg/L with the TDS entirely as NaCl)
Calcium and/or Magnesium	Hardness of the water meets typical value expected of the Australian standard (5-380mg/L)	VSD	Yes	National Water Quality Management Strategy; Australian Drinking Water Guidelines 6: 2004 NHMRC. (Based on EDIS N achievement of 300mg/L)
Heavy Metals	EDR provides a means by which to remove heavy metals	VSD	Unknown	Performance would have to be assessed in combination with given contamination level and

				with Villager A1 pre-treatment. System performance required (Pb < 0.01 mg/L, As < 0.007 mg/L, etc)
1.1.2 Energy Requirements				
Power Source	Provide enough energy required to run device	VSD	Yes	12V Auxiliary Power source. 240V is sourced from the solar-panels and converted to 12V
Electricity Use	Minimise electricity use and use during off-peak times	VSD	Yes	12V, 4 amp electricity. Designed so that it only runs during off-peak times.
1.1.3 Water Quantity Requirements				
Quantity	Produce enough water for 8 person crew (240L/day)	VSD	Yes	220L/hour. Use for 1 – 3 hours/day depending on number of occupants and required use.
Availability	Water should be available at all times for use	VSD	Yes	System will be used as required to prevent storage level dropping below 750L (3 days) supply of water
1.2 System Integration				
1.2.1 Processing workplace				
Water Processing Signage	Signage for water processing procedures is in accordance with relevant standard	VI	Yes	Signage as required for standards. AS 1319 Safety Signs for the Occupation Environment AS 4123.7 Colours, Markings, Designations
Crew Training about Workplace	Crew is aware of components of system and their workings	VT	Yes	Crew would be informed of system workings and an operation manual would be provided on-board.
System accessibility	System is accessible to allow for maintenance and repair	VI	Yes	System is mounted on the wall as described. System is easily accessible on wall.
1.2.2 Device Size and Positioning				
Size and Positioning	Sized and positioned for safety and space restrictions	VC	Yes	Located in Flight Deck. Easy access for better safety. See Section 5.3.4
Room	Device is to be positioned in the flight deck whilst not inhibiting room for the rover or other devices	VC	Yes	Located in Flight Deck. See Section 5.3.4
Weight	Weight is able to be supported by wall mounts used for system	VC	Yes	13.6kg. Manufacturer's wall-mount is designed to mount system on wall.

1.2.3 Usability				
Usage	System is able to be used by all inhabitants	VD	Yes	All crew members would be trained on how to operate the system and an operation manual would be provided on-board
1.3 Repairs				
1.3.1 Execution of Minor Repairs				
Personnel	Minor repairs should be performed by members of the crew using spare parts	VSD, VD	Yes	Spare-parts package would be available on-board. Instructions on how to perform basic repairs would be present.
Timing	Minor repairs should be able to be performed as quickly as possible	VNR	Yes	The system, instructions, and spare-parts package would be easily accessible. System can be turned off easily and repairs performed easily.
Procedure	Procedure given by manufacturer should be followed	VSD	Yes	Manufacturer's repair handbook will be on-site with details of relevant procedures
Temporary Repairs	Temporary Repairs should be performed where possible until expert is available	VNR	Yes	System is easily accessible and crew are trained in system functions. Spare-parts available
1.3.2 Majors Repairs				
Personnel	All major repairs should be performed by a qualified expert	VSD,VD	Yes	Contact details for an expert would be present on-board. Details for multiple experts would be present in case one is unable to attend.
Notification	Expert should be notified as soon as possible and organised to visit	VNR	Yes	Crew trained to inform an expert as soon as possible to organise a visit.
1.4 Maintenance & Lifetime				
1.4.1 Lifetime				
System lifetime	System lifetime should exceed lifetime of the habitat	VSD	Yes	System lifetime exceeds 20 years as smaller components can be replaced as necessary.
End of life	Able to be disposed of safely after lifetime	VSD	Yes	System contains standard components with no dangerous or harmful materials
Footprint	Footprint on the surrounding environment should be minimal	VSD,VI	Yes	System has no impacts on surrounding environment

1.4.2 Maintenance				
Expertise	System can be maintained by a non-expert member of the crew	VSD, VD	Yes	Two members of the crew will be trained at all times about maintenance of the system. System maintenance is simple and at the level where it can be completed by a non-expert. Tasks involved include cleaning filters, replacing carbon block and replacing UV lamp.
Scheduling	Scheduled maintenance should be performed as required	VI	Yes	Maintenance schedule will be drawn up and a checklist will be present at the device to ensure maintenance is being performed at required times.
Spare Parts	Spare parts for the system are kept in stock within the habitat.	VI	Yes	Spare parts are kept in the Flight Deck area. See Section 5.3.4.
1.5 Constraints				
Process inputs	System must be able to handle chemical and biological contaminants	VSD	Yes	Unit is designed for these inputs.
Low Cost	Minimise cost ($)	VD & VS	Yes	Achieved through design.
Maintenance	Able to be maintained by non-expert	VT	Yes	Unit chosen is easily maintained.
Power	Powered by electricity	VNR	Yes	Unit chosen uses electricity.

Water Storage Verification

Table 31: Water Storage Requirements Verification

Specification/Constraint	Required Performance	Verification Method	Requirement Met	Actual Performance
1 Store all water types separately				
1.1 Store fresh, potable water	More than 700 L of fresh water can be stored for the habitat	VC	Yes	1350L of fresh water are stored in the top-up tank
1.1.1 Operate with few refills during mission	The crew can survive 14 days between refills of the fresh water	VC, VS	Yes	The water storage lasts 14 days with 750L left at the end
1.1.2 Foolproof fresh water against overuse	Fresh water is not used where recycled grey water can be	VI, VS	Yes	Fresh water use is controlled by the computer
1.2 Store recycled grey water	More than 480 L of recycled grey water can be stored for the habitat	VC	Yes	1000L of water is stored in the post-processing tank
1.2.1 Low storage times for grey water	Grey water is stored for a maximum of 2 days	VS	Partial	Grey water is stored for 1 day at most, while post-processed water is stored for up to 4 days
1.2.2 Allow grey water disposal	Grey water can be removed from the system if contaminated	VI	Yes	Water can be drained directly from habitat
1.3 Store grey water to be recycled	More than 384 L of grey water can be stored before running through the recycling system	VC	Yes	500L of grey water is stored in the pre-processing tank
2 Lifetime				
2.1 Longer than habitat	The lifetime of the water storage system is longer than 5 years	VSD, VC	Yes	Tank lifetimes are in the range of 10-20 years
2.2 Does not introduce contaminants	The storage materials must meet AS4020 to prevent contamination of water	VSD	NA	Detailed design will ensure the system conforms to this requirement
2.3 Minimises water losses	The entire system must lose less than 48 L/day	VS, VD	NA	More accurate water system modelling will be required to determine losses

Specification/Constraint	Required Performance	Verification Method	Requirement Met	Actual Performance
3 Maintenance				
3.1 Low frequency	The MTTF and MTBR for all components must be maximised	VT, VSD	NA	Detailed design must be done to ensure these values are met
3.2 Low downtime for urgent maintenance	Urgent maintenance takes the water system offline for less than 5 hours	VSD, VD	Yes	Instrumentation is located in accessible places, and may not cause system downtime
3.3 Large-scale maintenance not urgent	Any maintenance which requires more than 5 hours downtime can be deferred to between missions	VSD	Yes	No system within the water storage will require more than 5 hours' downtime within a mission
4 Storage Constraints				
4.1 Location	The storage system must fit within the base design	VC	Yes	The tanks and other systems all fit within the habitat nose
4.2 Safety	Recycled water must be safe to use as grey water after storage	VT	NA	System testing is required to verify performance
4.3 Obtrusiveness	The system should be unobtrusive, not making undue background noise	VS, VT	NA	System testing is required to verify performance

19. Appendix VII: Power System Design Verification

Table 32 - Power System Design Verification

Specification/Constraint	Required Performance	Verification Method	Requirement Met	Actual Performance
1 Primary Power Generation				
1.1 Provide power				
1.1.1 Provide appropriate voltage	240V	VS, VT	Yes	Produces 48V with inverters to run AC appliances.
1.1.2 Produce sufficient power	250kWh/Day	VS, VC	Yes	
1.1.3 Provide appropriate wattage	Power appropriate for all appliances	VS, VT	Yes	Inverters maximise power output.
1.2 Upgrade				
1.2.1 Increase capacity	Capacity can be increased onsite	VS	Yes	
1.3 Transport				
1.3.1 To/from deployment site	Can be transported in the cargo module	VD	No	Will most likely require separate transport.
1.4 Deployment				
1.4.1 Deploy at site	Maximise ease	VD	Yes	Will require electrical expertise to deploy solar panels
1.4.2 Pack up for removal	Maximise ease	VD	Yes	Will require electrical expertise to deploy solar panels
1.5 Maintenance				
1.5.1 Cleaning	Maximise ease	VD	Yes	1570mm x 780mm x 1050 mm
1.5.2 Electrical Maintenance	Maximise ease, safety	VD	Yes	A small shack is built around the generator on location

2. Backup Power Generation				
2.1 Provide power				
2.1.1 Provide appropriate voltage	240V	VS	Yes	It can continuously generate 10.6kW (11.6kW peak) at 240V.
2.1.2 Produce sufficient power	8.8kW continuous	VS, VC	Yes	It can continuously generate 10.6kW (11.6kW peak) at 240V.
2.2 Maintenance				
2.2.1 Cleaning	Maximise ease	VD	Yes	May require cleaning for continued use (e.g. removal of dust).
2.2.2 Engine Maintenance	Maximise ease, safety	VS	Yes	Check all spark plugs or glow plugs (for diesel systems), air and oil filters. Lubrication of any internal combustion engine is a necessity. Keep the engine running for several minutes before shut down.
2.2.3 Power Regulator	Maximise ease, safety	VS	Yes	Make sure there is no oil or other contaminants in the casing. Also, when running the generator during its regular run up and shut down, look for any sparking or open wires.
2.2.4Transformer	Maximise ease, safety	VS	Yes	A voltage meter is a simple tool to test a transformer. Check the voltage for specified readings.
2.2.5 Externally	Maximise ease, safety	VS	Yes	Components will need to be isolated for repair/maintenance.
2.3 Store				
2.3.1 Size	Minimize	VS	Yes	1570mm x 780mm x 1050 mm
2.3.2 Location	Protectable	VD	Yes	A small shack is built around the generator on location.
2.4 Other Factors				
2.4.1 Noise level	Minimize	VS	Yes	51 dB @ 7 m (50 Hz)
2.4.2 Transport	Minimize weight	VS	Yes	750kg.
2.4.3 Service life	Maximize	VS	Yes	12 month/1000 h conditional warranty

2.5 Simulation				
2.5.1 Can be started without breaking simulation	Can be started without breaking simulation	VS, VD	Yes	It can start immediately either by a push of a button or automatically.
2.5.2 Accommodate all the loads at start up	Sufficient surge capacity	VS	No	Requirement was not investigated. Manufacturers should be contacted with a list of requirements to ensure all loads can be accommodated at startup.
2.5.3 Start-up	It can start immediately	VS	Yes	It can start immediately either by a push of a button or automatically.
2.5.4 Computer Applications	Prevent data loss during the transfer time	VS, VD	Yes	A UPS system is used to avoid data loss.
2.6 Safety				
2.6.1 Meet required safety standards	Must meet Australian safety standards	VS	Yes	Generator is sold within Australia, so must meet standards.
3. Climate Control				
3.1 Air conditioning				
3.1.1 Cool habitat to liveable temperature	Habitat is kept at 15-25°C	VS, VC	Yes	Habitat is kept at 15-25°C.
3.2 Heating				
3.2.1 Warm habitat to liveable temperature	Habitat is kept at 15-25°C	VS, VC	Yes	Habitat is kept at 15-25°C.
3.3 Operation				
3.3.1 Thermostat	Automatically operated with thermostat	VS	Yes	Automatically operated with thermostat.
3.3.2 Manual Override	Thermostat control can be manually overridden	VS	Yes	Thermostat control can be manually overridden.

20. Appendix VIII: Power System Design Requirements

Item	Quantity	Power Consumption (kW)	Estimated daily operation (h)	Energy Consumption per Day(kWh)	Vital Power Usage (kW)	Low Power Usage (kW)
General						
Hot Water System	1	3	3	9	0.375	0.375
Water Pump	1	1	6	6	0.25	0.25
Interior Lighting	16	0.006	15	1.44	-	0.096
Exterior Lighting	20	0.006	24	2.88	-	-
Emergency Lighting	6	0.01	24	1.44	0.12	0.12
Vacuum Cleaning System	1	1	1	1	-	-
RC Air Conditioning	1	5.5	24	132	4	4
Rover	1	0.1	10	1	-	-
Water Recycling	1	N/A	N/A	1	-	0.0520
Miscellaneous	1	1	20	20	-	-
Laundry						
Dryer	1	1 per load	1 load per day	1	-	-
Washing Machine	1	0.2 per load	1 load per day	0.2	-	-
Incinerating Toilet	1	N/A	N/A	50	2.1	2.1
Wardroom/Mess						
TV	1	0.08	6	0.48	-	-
Radio/ Sound System	1	0.06	6	0.36	-	-
VCR	1	0.02	2	0.04	-	-
Drinks Fridge	1	0.035	24	0.84	-	-

Microwave	2	1	1	2	-	1
Electric Stove	1	4	2	8	-	-
Electric Kettle	1	2	1	2	-	-
Exhaust Fan	1	0.3	1	0.3	-	-
Waste Incinerator	1	0.5	2	1	-	0.5
Lab						
Lab Fridge and Freezer	1	0.0834	24	2	0.0834	0.0834
Centrifuge	1	0.25	3	0.75	-	-
Electrophoresis Tank	1	0.06	3	0.18	-	-
PCR Machine	1	1.2	3	3.6	0.15	0.15
Personal Laptop	8	0.05	12	4.8	0.1	0.1
Fax, Printer and Photocopier	1	0.2	1	0.2	-	-
Total				**253.51kWh**	**7.1784kW**	**8.8264kW**

21. Appendix IX: Martian Designs' Project Team Structure

21.1.1. Personnel

The project team consists of the following members:

Table 33: Martian Designs' Project Team and their disciplines

Name	Employee ID	Degrees	Disciplines / Strengths
Michael Gill	U4520969	Engineering	Mechatronics / Electronics and Communications
Alistair Watson	U2563373	Engineering / Chemistry	Mechanical / Chemical Engineering / Chemistry
James Everdell	U4399186	Engineering	Renewables / Mechanical - Construction
Elliot Wise	U4528220	Engineering / Science	Mechatronics / Computational Modelling
Rebecca (Bec) Beasley	U4527711	Engineering / Science	Telecommunications / R&D / Math
Sathyan Pooranachandran	U4474983	Engineering	Mechatronics / Materials
Phil Watt	U4303184	Engineering / Science	Mechatronics / Electronics / Math / Computational Modelling
(Olivia) Jiazhen Zhu	U4795492	Engineering	Telecommunications / Electronics
Jared Dean	U4538308	Engineering / Commerce	Mechanical / Materials & Manufacturing / Management
(John) Hung Yip Lui	U4361832	Engineering	Mechanical / Mechatronics
Charles Boettcher	U4667770	Engineering	Sustainable / Mechanics & Materials /Manufacturing

Emily Carrie	U4539793	Engineering	Mechatronics / Electrical/ Communications, Computational Modelling
Yifei Wang	U4830143	Engineering	Communications

The project team has a vast amount of electrical engineering experience with a total of six electrical engineering majors. Other areas of expertise include mechatronics (6 team members), communications (4 team members), materials (4 team members), mechanical (4 team members), manufacturing (3 team members) and sustainability disciplines (2 team members). The project team is well rounded and has a vast range of knowledge from almost all of the engineering disciplines. The team also has some additional experience in the fields of computational modelling, commerce, chemistry, research and development and science. The following personnel matrix summarises the design teams' abilities.

Table 34: The Martian Designs' Project Team with their disciplines and capabilities listed

	Engineering Diciplines							Additional Capabilities										
	Manufacturing	Mechanical	Mechatronics	Materials	Electrical	Communications	Sustainable	Chemistry	Computational Modelling	Research and Development	Science	Administration	Commerce	Planning and Scheduling	Documentation	Specification preparation	Project Management	Presentation Skills
Project Members																		
Michael Gill			MG		MG	MG				MG								
Alistair Watson		AW						AW										
James Everdell	JE			JE			JE							JE	JE	JE	JE	JE
Elliot Wise			EW		EW				EW	EW	EW							
Rebecca (Bec) Beasley						RB				RB	RB							RB
Sathyan Pooranachandran			SP	SP				SP				SP						
Phil Watt			PW		PW				PW		PW				PW			PW
(Olivia) Jiazhen Zhu					JZ	JZ							JZ					
Jared Dean	JD	JD		JD								JD	JD	JD			JD	
(John) Hung Yip Lui		HL	HL							HL								
Emily Carrie			EC		EC	EC			EC						EC			
Charles Boettcher	CB	CB		CB			CB											CB
Yifei Wang					YW													
TOTAL	3	4	6	4	6	4	2	2	3	4	3	2	2	2	3	1	2	4

21.1.2. Personnel Role Descriptions

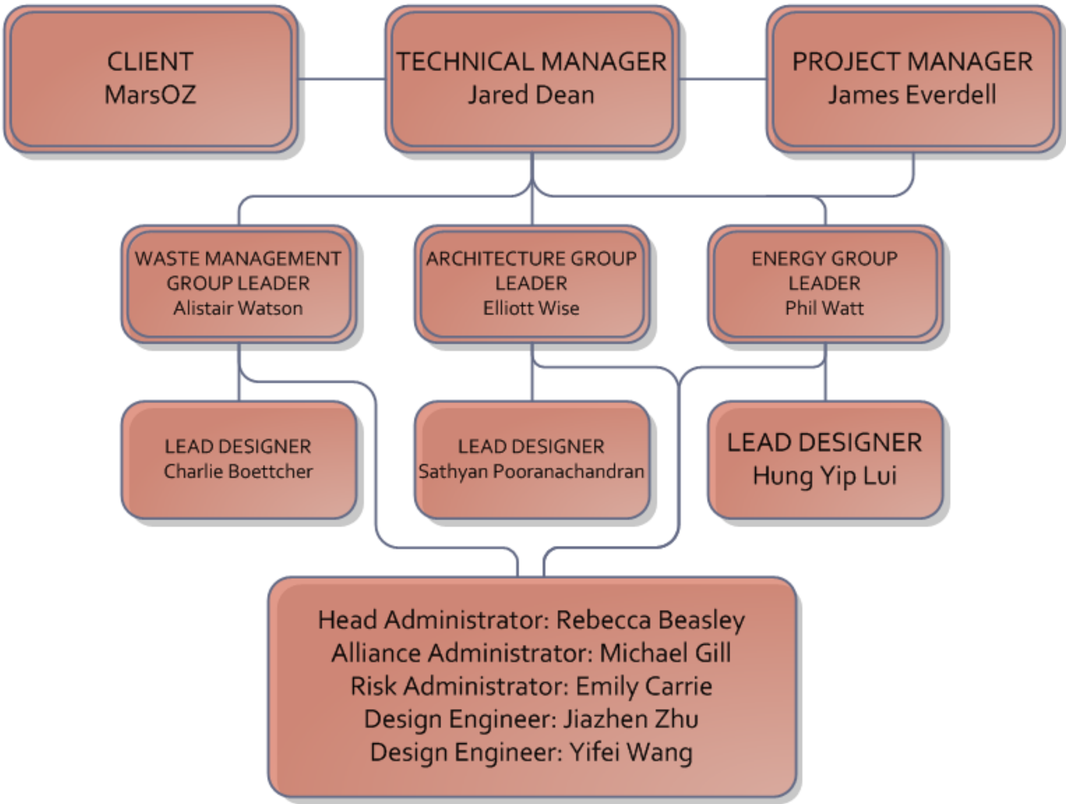


Figure 42: Martian Designs' Project Team Organizational Chart

Project Manager: James Everdell

The project manager's role is to oversee the successful completion of the project by ensuring the whole team works effectively and to schedule. They will play a role in developing work packages for the design teams to complete.

Technical Manager: Jared Dean

The technical manager's role is to facilitate communication between the client and the project team. They will also work closely with the group leaders to compile and find solutions to work packages that are required throughout the project.

Group Leaders: Alistair Watson, Elliott Wise and Phillip Watt

The group managers' will be responsible for completing work packages. They will delegate tasks to their design team and compile the relevant sections of the design report. They will also convey questions to the technical manager that are to be passed on to the client.

Lead Designers: Charlie Boettcher, Sathyan Pooranachandran, (John) Hung Lui

The lead designers will remain with the group leader throughout the project and will assist in managing the work packages.

Design Team: (Olivia) Jiazhen Zhu, Emily Carrie, Yifei Wang, Michael Gill and Rebecca Beasley

The design team will be assigned a specific group to start with and will assist in carrying out the work package tasks. Every few weeks the design team will shift groups to provide new perspective and ideas and will assist other groups when they are struggling with the workload.

Head Administrator: Rebecca Beasley

Rebecca will be responsible for general administration tasks including meeting minutes and ensuring attendance at project meetings.

Alliance Administrator: Michael Gill

Michael has been assigned the role of looking after the alliance group which provides a forum for announcements and discussion and a collection point for project resources.

Editor: Charlie Boettcher

Charlie will be responsible for designing a template for our reports and documents to adhere to. He, along with others, will conduct the final edit ensuring the final deliverable is coherent, professional and meets the requirements of the project scope.

21.1.3. Personnel Communication Matrix

The following project team matrix is a diagrammatic representation of how the various teams within the project will interact with each other. Notice that the Technical Manager sits among all design teams and will contribute and facilitate interaction between them. The Project Manager has responsibility of bringing the whole project together and as such, all disciplines sit within the Project Manger's scope.

Figure 43: Martian Designs Project Team Communication Matrix

21.1.4. Work Breakdown Structure

The following product based simple work breakdown structure demonstrates what each stage of the project consists of and what level of design team personnel are responsible for each section.

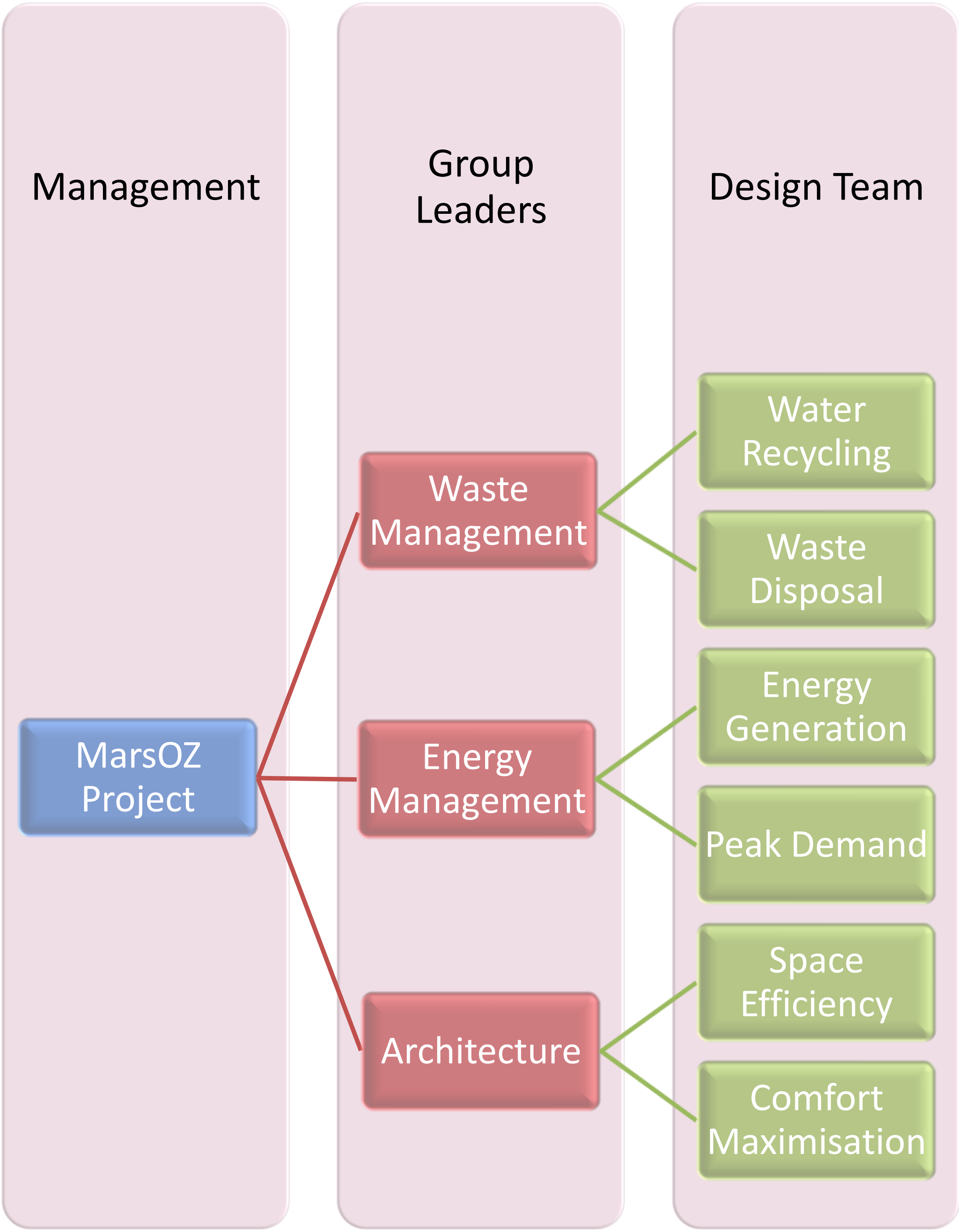


Figure 44: Project Work Breakdown Structure