Northdonning Heedwell

aresam

expanding new horizons

University High School, Irvine, California, USA

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University High School ISSDC 2010

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1.0

Executive Summary

SECTION 1: EXECUTIVE SUMMARY

As humans, we are constantly searching for new frontiers: new ways to expand our horizons. Our journeys have taken us around the world, to the Moon, and now, in 2055, to Mars. We at *Northdonning Heedwell* are proud to present a design to make this journey a success. An orbiting link between familiar land and this new frontier, ***Aresam*** will provide not only a means to explore new ground on Mars but also a comfortable residence for transient and permanent residence as well as a bustling trade center.

Aresam's innovative design is centered around the comfort and well-being of its residents while ensuring smooth operations between Mars, Earth-based settlements, and Earth:

- A pressurized *adjustment module,* called **Watson**, provides incoming residents and tourists with a chance to acclimate themselves to the settlement environment.
- A *manufacturing sphere*, **Graff**, will not only serve as a center for production but also as a launch site for prefabricated Mars bases, ready for research and exploration.
- **Pascal,** a *port facility,* will provide a hub for incoming and outgoing traffic as well as extensive repair facilities equipped with state-of-the-art
- Several new *construction technologies* will be implemented that will facilitate rapid assembly and smooth repairs, essential on this settlement.
- Carefully planned *community designs* will provide optimal comfort for residents, fostering a modern, progressive environment.

Not only will Aresam be able to house the requested 20,000 full-time residents in its spacious residential torus, **Gauss**—the settlement has a great deal of room for further expansion. Additionally, Aresam will have the capacity to support more than 2,000 visitors at the height of its bustling success. Safety and contingency plans have been defined in detail to ensure the utmost safety of this population. Aresam's vast array of automated systems, designed to facilitate and smooth operations and maintenance of the settlement, will be monitored at every step by trained technicians.

Construction of Aresam will begin as soon as its design is approved: Foundation Society members are projected to be able to move in by April of 2077. All other venturers will be able to settle by September of 2077, and the full population is expected to be established no later than July of 2078. The settlement's exports and services will ensure that it pays for itself in less than twelve years.

Aresam will fulfill a role far greater than that of a simple outpost: it is the future of space exploration. A feat of engineering and design, the settlement will be a reliable station for years to come, establishing itself as a center for research, business, tourism, trade, and exploration. Northdonning Heedwell is pleased to present the Foundation Society with this paragon of pioneering: Aresam.

2.0

Structural Design

SECTION 2 : STRUCTURAL DESIGN

Aresam's innovative structure provides stability and efficiency, ensuring over 20,000 residents a comfortable experience on the settlement.

2.1 External Configuration

2.1.1 Exterior Design

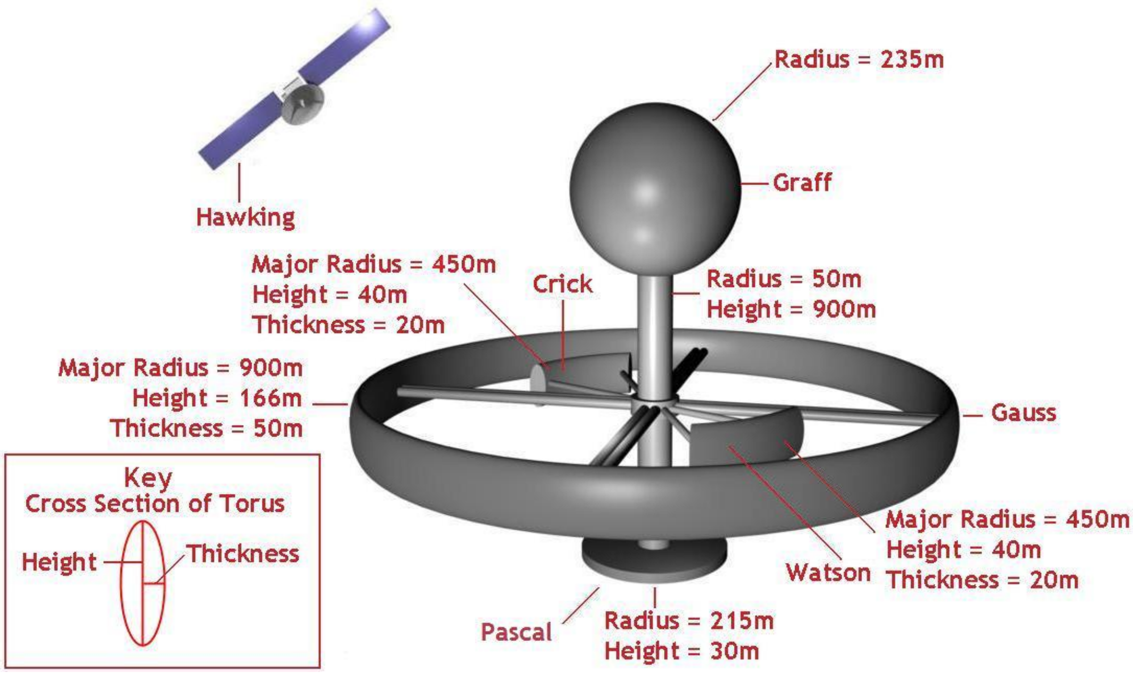


Figure 2.1.1 Overall External View with Hawking Satellite

Aresam will consist of one pressurized residential torus, *Gauss*, maintained at one Earth gravity and connected to the Central Axis by four pairs of spokes. To reduce costs, the settlement's manufacturing module, *Crick*, adjustment module, *Watson*, and Gauss will all be connected to the same rotating section of the Central Axis. Pascal is located at the bottom of the Central Axis. Here, ships dock, load and unload cargo/settlers, and depart. *Pascal's* cylindrical design maximizes docking area while minimizing volume and construction materials. The manufacturing and prefabricated base launching sphere, *Graff*, is located on the top of the Central Axis. By placing manufacturing next to the pre-fabricated base launcher, transportation costs are lowered as the parts for the prefabricated base are produced near the launcher. Furthermore, a spherical design maximizes volume and minimizes construction materials needed. Operations in Aresam will be powered by solar energy that is gathered and beamed to Aresam by the five satellite system, *Hawking* (only one is shown).

Several factors were considered when designing Aresam's structure. In order to minimize material waste and avoid pressure points, the cross-section of the torus was designed as an oval. A pair of spokes, placed at ninety degree angles of the residential torus, stabilizes the torus. These pairs of spokes divide *Gauss* into four separate volumes, designed to promote redundancy. Each section can operate independently; in case of a breach in one sector, the residents can relocate to the adjustment torus Watson or to the Central Axis for temporary living space. Furthermore, the paired spokes design allows settlers to have a minimum of two locations to exit the torus during an emergency even after isolating volumes of the torus by airlocks in between each pair of spokes. To minimize the chance of accidents, ports are placed at one end of the Central Axis to increase distance between them and the residential torus. *Graff* is placed at the other end of the Central Axis to have a clear base launching area away from residency torus to again avoid accidents.

Sections:	Dimensions: (m)	Total Surface Area: (m^2)	Total Volume: (m^3)
Central Axis	Radius = 50 Height = 900	298451.3	7068583.5
Pressurized Rotating Torus *Gauss*	Radius = 900 Height = 166 Thickness = 50 Circumference = 5654.9	188781068	36862972
Adjustment and Manufacturing Modules *Watson* and *Crick* *Dimensions are per module*	Radius = 450 Height = 40 Thickness = 20 Length (arc length) = 392.7	872358.02	246740.11
Port Pascal	Radius = 215 Height = 30	289026.52	3769911.2
Manufacturing and Prefabricated Base Launching Sphere *Graff*	Radius = 235	696934.06	54359992.42
Hawking Satellite System	Width of one panel = 592 Height of one panel = 100	1184000	N/A

Table 2.1.1 Dimensions

2.1.2 Construction and Radiation Debris Penetration Protection Materials

Material	Usage	Properties
6061-T6 Aluminum Alloy	Structural Support	Light weight material lowers second particle showers. Has good weldability, high tensile and yield strength. Moderate amounts of Aluminum on Mars enable Aresam to independently produce the alloy and minimize transportation costs.
Polyethylene Foam	Radiation shielding and shock absorbency for hull components	Lightweight property and high H concentration act as radiation protection against secondary particles. Foam structure allows the material to absorb shocks.
Silica Aerogel	Radiation shielding and thermal insulator for hull components	Outstanding radiation protection and thermal insulation properties.
Polyethylene	Radiation shielding for hull components	Lightweight property and high H concentration act as radiation protection against secondary particles.
Steel Alloy Grade 18KhGNMFR	Structural Support	Very high tensile strength. The abundance of Iron on Mars makes producing this material on the settlement very feasible and cost-efficient.
Regolith (Martian)	Radiation shielding (torus hull components) Growth median	Provides radiation protection as well as a growth medium for plants.
Raguard	Radiation shielding for hull components	Has diverse applications through its ability to be coated. Provides X-ray radiation shielding.
Demron Cloth Layers	Radiation shielding for junctions	Flexible material that protects against gamma-rays, X-rays, and other radiation. (Not shown)
Fused Silica Glass	Thermal insulator for hull components	Low coefficient of thermal expansion, good thermal insulator, and resistant to thermal shock.

Table 2.1.2 Hull Components

Figure 2.1.2 Radiation/Debris Protection Layers

Radiation and debris protection shielding will be about 14.54 m. This shielding will be used throughout Aresam with the exception of the spokes. The shielding for the spokes will not contain regolith or fused silica glass, because settlers will be thermally protected by their space suits while in the spokes. Due to its flexible property, Demron Cloth layers will be used at junctions to provide additional radiation shielding to further prevent the accelerated corrosion of the metallic support.

2.1.3 Artificial Gravity and Rotation Rates

The residential torus *Gauss* will be maintained at one Earth gravity in order to simulate an Earth environment to enable settlers, animals, and tourists to easily adjust to the settlement. However, there is an adjustment module for people who cannot immediately become accustomed to one Earth gravity. In order to achieve this gravity, *Gauss* will rotate at .9965 rpm. Calculations are shown below:

Given that:
The centripetal acceleration due to velocity is $a_c = (v_t)^2 / r$
And that $v_t = 2\pi r/p$, and centripetal acceleration = 1 g = 9.8 m/s^2

a_c = acceleration towards center of mass
v_t = velocity of object(in meters/second)
r = radius (900m)
p = period of rotation (in seconds)

We have: $9.8 = (4\pi^2 \times 900)/p^2$, and p = 60.213 seconds
Using proportions, 60.213/60 = 1/x, we get x = to 0.9965 rpm.

The manufacturing and adjustment modules, *Crick* and *Watson* respectively, will be maintained at half Earth gravity due to their shortened distance from the Central Axis. With less gravity, friction decreases and therefore efficiency in *Crick* increases. Furthermore, the half Earth gravity environment provides a transition between zero gravity and one Earth gravity. Using similar calculations, with a_c = 4.9 m/s^2 and r = 450m, *Crick* and *Watson* will be rotating at .9965 rpm. Due to similar rotation rates, *Gauss*, *Watson*, and *Crick* will be connected by spokes to the same rotating section of the Central Axis. The rotation of these components will be powered by xenon ion propulsion motors and monitored by central processors in the *Central Axis*.

Since the consequences of the Coriolis Effect are directly proportional to rpm and humans cannot withstand 3 rpm for an extended period, the .9965rpm of the Watson, Crick and Gauss tori were chosen to maximize the comfort of the settlers.

In order to prevent to unnecessary use of energy and resources, *Pascal,* the *Central Axis,* and *Graff* will not have artificial gravity and therefore will not be rotating. This lack of artificial gravity will increase the efficiency of transportation and provide areas for zero gravity recreation.

The spokes will unavoidably have artificial gravity and rotate at .9965 rpm but this is insignificant as the Magnetic Railway Pods will carry out the transportation in the spokes (see section 3.2.7 for more details on the Magnetic Railway Pods).

2.1.4 Pressurized and Non-Pressurized Volumes

Gauss and *Watson* will be maintained at .7 atm, a pressure that saves air and can be easily and comfortably adjusted to. Due to pressure dependent manufacturing processes, only half of *Crick* will be non-pressurized. With minimal human activity in the Central Axis and the spokes connecting the rotating sections to the central axis, these areas will not be pressurized. Due to their constant exposure to the vacuum of space, *Pascal* and most of *Graff* will not be pressurized to reduce excessive air usage. However, since *Graff* will contain pressure dependent manufacturing, half of the manufacturing portion of the sphere will be pressurized.

2.1.5 Volume Isolation

Aresam will have the ability to isolate any combination of its ten separate volumes at the same time. The torus will be able to divide into four separate sections separated by an airlock in between the two spokes every ninety degree angle. As a result, the overall number of airlocks in the torus will be four. Since the manufacturing and prefabricated base launching sphere is already separate into sections in

Graff, these two sections can be separated into two separate volumes by airlocks. The *Central Axis*, *Pascal*, *Watson*, and *Crick* will each be separate volumes that can be isolated in Aresam through air locks. As shown, ten separate volumes can be isolated in Aresam.

2.2 Interior Allocations

2.2.1 Pressurized Rotating Residential Torus (Gauss)

Aresam focus on creating a safe and comfortable living environment through careful planning of area allocations. The calculations for down area can be found in the data table below:

Section (1 sector in one torus)	DA (Down Area) (m^2)	% DA of total DA	Total DA* (m^2)
RESIDENTIAL NEIGHBORHOOD			
Residential	23250	10.77943	465000
Hospitals/Health Research	1312.5	0.608516	3937.5
Schools	2812.5	1.303964	5625
Recreation/ Open space	61875	28.6872	93000
AGRICULTURAL/FOOD PRODUCTION/WASTE PROCESSING			
Agricultural	30937.5	14.3436	247500
Livestock	28125	13.03964	28125
Processing, Drying, Storing	15750	7.302197	67500
Waste and recycling	11250	5.215855	22500
COMMERCIAL			
Shops & Business	3712.5	1.721232	18562.5
Service industry	22500	10.43171	22500
MISCELLANEOUS			
Electrical distribution	562.5	0.260793	13500
Communications	1.004464286	0.000466	4.017857
Entrances to Communities	100	0.046363	200
Miscellaneous	13500	6.259026	13500
TOTALS:**	215688.5045	100	1001454

Table 2.2.1: Residential Torus Allocations

* Total DA refers to the total units of area one needs if one assumes that everything is built on only one level.
**The calculations are approximate, and due to rounding errors during calculations, totals may not add up completely.

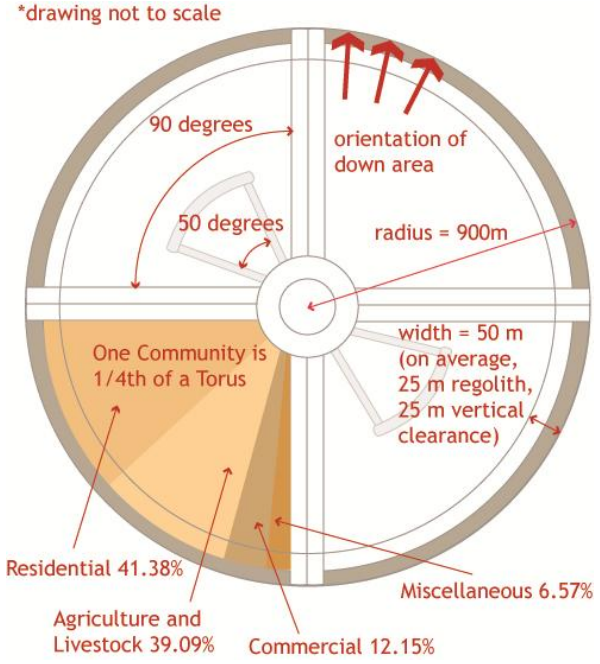


Figure 2.2.1 Top view of a Residential Torus Gauss Smaller modules rotating at ½G are drawn in light grey.

Initially, though the whole external structure of torus Gauss will be built, only one sector will be populated. The interior of the other sectors are largely undeveloped in order to lower initial building costs and save resources and maintenance efforts. For more information about expansion, see Section 2.4.

Gauss will contain all living areas. Each Community is physically separated from the others via advanced airlock systems, though residents can easily traverse to other Communities. Sectioning the torus ensures that if one Community is harmed, the others will be safe. Residents can then easily take shelter in the neighboring Communities while repairs are being made.

Gauss features luxurious housing, shops, businesses, schools, advanced health care and health research centers, a beautiful varied landscape, a complex LED day and night cycle system, and more to simulate realistic Earth life.

2.2.2 Smaller Rotating Torus Sections (Watson and Crick)

Two smaller pressurized torus segments, Watson and Crick, will rotate synchronously with the large torus. The radius is set so that half G is simulated in both segments. One torus segment is dedicated completely to manufacturing that would not be possible in zero G and other lighter manufacturing tasks. The other torus segment serves as extra emergency living space in case the large torus is damaged or malfunctions. It can support up to 1000 people. The residential torus includes service industries, waste treatment plants, hospitals, small areas of recreation, and compact houses.

Torus Segment	Down Area (m^2)
Manufacturing (Crick)	15707.96
Residential (Watson)	15707.96

Table 2.2.2: Residential Torus Allocations

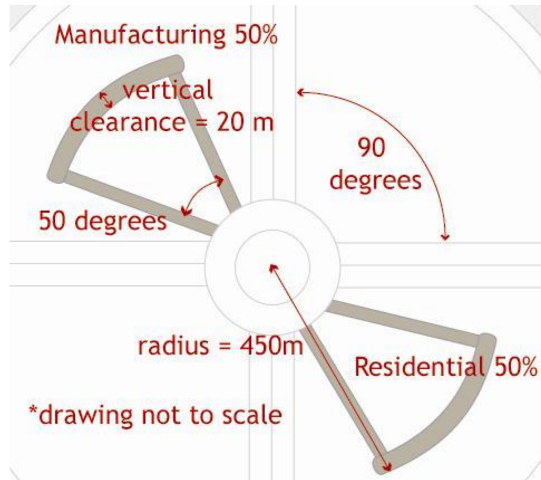


Figure 2.2.2 Top view of the two small rotating modules Crick and Watson. Larger torus can be seen in light grey.

2.2.3 Central Axis

The Central Axis will host a control system, ample storage space, a zero-G research facility, and temporary shelter for 2000 people. It is the center of heavy transportation within the settlement and is thus fitted with an extensive transportation system. Its zero-G, unpressurized environment (with exception to the temporary living area) makes it an ideal place to transport cargo as little energy is needed in zero-G to move objects around.

Due to its zero gravity nature, the tables will provide volume allocations rather than down area allocations, as no specific area can be declared as "down".

Section	Volume (V) (m^2)	% Volume out of Total V
Storage	5,000,000	70.73553
Transportation	1620000	22.91831
Control Systems	500	0.007074
Zero-G Research Facilities	4500	0.063662
Emergency Living Space (2000 people)	124000	1.754241
Miscellaneous	319,583	4.521181
TOTALS:	7068583.471	100

Table 2.2.3: Central Axis Allocations

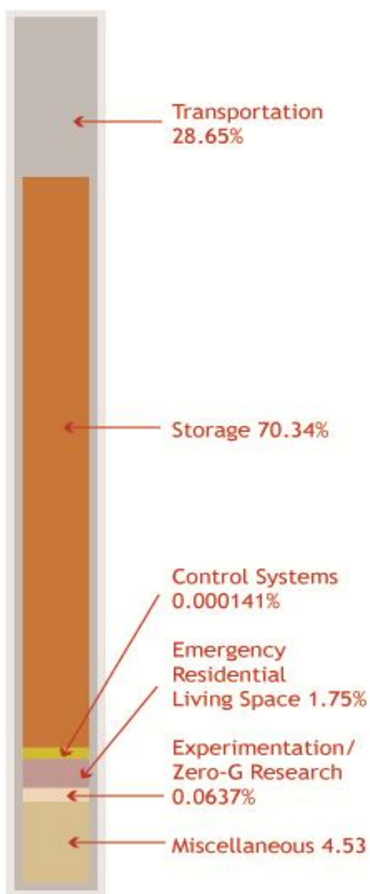


Figure 2.2.3 The Central Axis

2.2.4 Manufacturing Sphere (Graff)

Sections	Volume (V)	Volume % out of Total V
Manufacturing (General)	4,000,000	7.311368
Manufacturing (Prefabricated Base)	15,339,401	28.038
Storage	35,000,000	63.97447
Central Axis and Transportation	369922.535	0.67616
TOTALS:	54,709,323	100

Table 2.2.4: Manufacturing Sphere Allocations

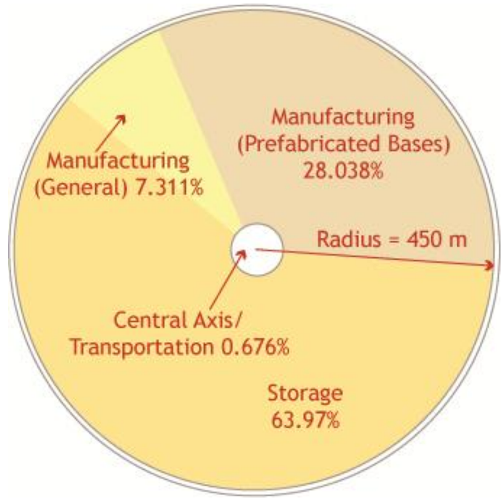


Figure 2.2.4
Top view of the Gauss Manufacturing Sphere

The Graff Manufacturing Sphere will be the center of manufacturing and construction. Its unpressurized, zero-G environment reduces manufacturing costs, efforts, and energies, making this an ideal place for heavy industry and refinement of raw materials. The Central Axis provides most of the transportation in this region. The top of the Central Axis can be easily modeled and fitted together with another Axis when the settlement expands. Heavy industry will not be ongoing in this top region of the sphere. Instead, light, simple tasks that can be easily moved around to other parts of the Graff Sphere are placed here, so that if the settlement does expand, clearing out the area for the new Axis will be less difficult.

2.2.5 Ports and Docking (Pascal)

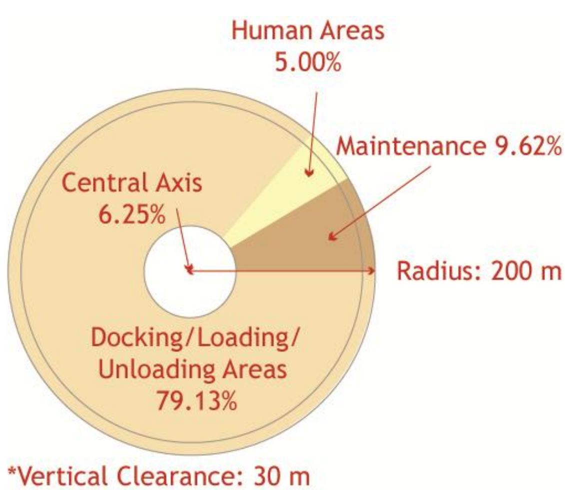


Figure 2.2.5 Top view of the Pascal Port

Sections	Volume (V)	Volume % out of Total V
Docking	2983041.735	79.12764
Maintenance	362812.5	9.6239
Human Areas	188437.5	4.99846
Central Axis	235619.449	6.25
TOTALS:	3769911.184	100

Table 2.2.5: Port Allocations

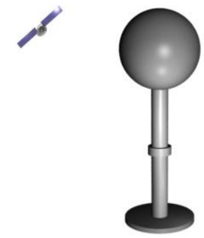
The Pascal Port will operate in zero gravity and mainly zero Pascals. It will contain areas for docking, maintenance of ships, and pressurized human areas for the comfort of visitors. Pascal Port is extremely versatile and can accommodate almost any vehicle or spacecraft. At the bottom of the Central Axis (not shown – below the plane of the diagram) is a "clamp" that docks larger ships, or ships that could possibly be constructed in the future. For more detailed information regarding the workings of Pascal Port, please see *Business, Section 7.1.1*.

2.3 Construction Process

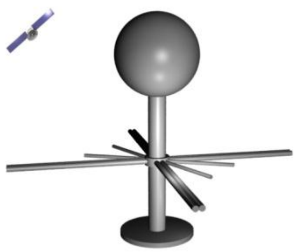
The construction of a space settlement is a difficult and time-consuming task. *Aresam*'s construction has been divided into seven distinct phases not only to ensure maximum efficiency but also to provide a more comprehensible outline of the construction process.

Phase 1:
Estimated time: 3 years.
Hawking and the *Central Axis* are built. Satellites will power the *Central Command System and Communication Systems,* which monitor construction processes.

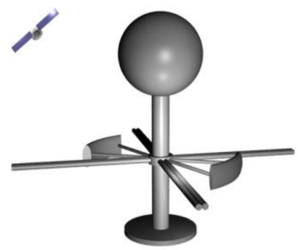
Phase 2:
Estimated time: 5 years.
Pascal is built. Operations begin to import resources for construction. Mining also begins on Phobos, Deimos, and Mars.



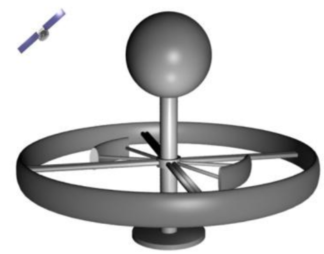
Phase 3:
Estimated time: 3 years.
Graff is constructed. Manufacturing operations begin to create construction materials with resources mined from Phobos, Deimos, and Mars.



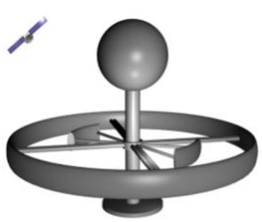
Phase 4:
Estimated time: 3 years.
Spokes for the manufacturing modules and residential torus are built.



Phase 5:
Estimated time: 3 years.
Watson and *Crick* are built. As rotation of the settlement will not begin until construction of Gauss is complete, the modules will temporarily operate in zero gravity.



Phase 6:
Estimated time: 3.5 years.
Gauss is built and attached to the spokes. Interior construction of one sector will begin during this phase using the interlocking panels as described in Section 3.3.2.



Final Phase:

Estimated time: 0.5 year. The settlement begins producing artificial gravity by rotation using ion thrusters. All parts of the settlement are tested and debugged. The settlement is now open to residents.

2.4 Expansion Capabilities

To minimize initial construction costs, Aresam's permanent residence areas are placed in one torus. By segmenting parts of the torus, communities in the torus can be built as needed. As a result, when operations in Aresam initiate, not all down area in the torus will available for residency. For future expansion, communities will be built in segmented sections of the torus and these sections will be connected to existing communities. If the population capacity of the torus is exceeded, there is space allocated on the central axis to construct another torus. In an emergency, any settlers that cannot be accommodated in the residential torus can temporarily reside in either the adjustment module or the emergency living quarters in the Central Axis.

To accommodate future unknown vehicles, the entry of the port and the docking area were designed to accommodate a ship that is at most 30m long, 10m wide, and 10m tall. Since any ships smaller than these dimensions can accommodated and these estimated ship dimensions are extremely large, *Pascal* is flexible. In case ships are larger than the estimated dimensions, *Pascal* has a clamp at the bottom of the cylinder that can attach to ships of any size. Once clamped, packages and settlers will come into the settlement through a hatch in the port end of the *Central Axis*. To reduce initial costs, *Pascal* will only have two levels that can contain approximately 16 freight ships per dock with 5 docks per level. For future expansion, more levels can be added to the top of the cylinder to increase the carrying capacity of the ports (see Section 7.1 for more details on the port).

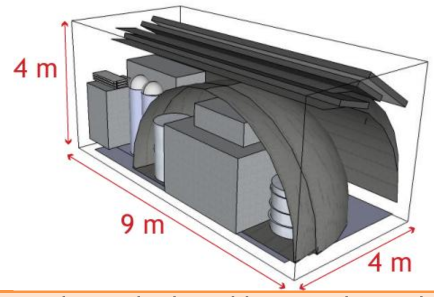
2.5 Prefabricated Base Structure

One of the principle functions of *Aresam* is to act as a proxy to surface operations on Mars. It is expected that scientists and engineers will make frequent trips to the planet. *Aresam* will use prefabricated structures that will enable explorers on Mars to set up surface bases relatively quickly.

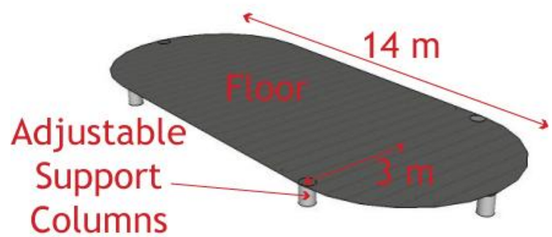
The structures will arrive on Mars along with settlers. Upon arrival, it will take less than 10 hours for two people to deploy the prefabricated structure, as the deployment process is almost entirely automated (see Section 5.5). Each structure will have enough provisions (including food, water, and oxygen) to accommodate 4 people for 30 days. The structures will contain research facilities, as most explorers will be scientists who wish to study Mars.

The prefabricated structures will be built on *Aresam* using materials mined from Phobos and Deimos. All materials and robots required to construct the base will be contained within a single 4m x 4m x 9m cargo container. The undeployed structure itself is a dome that is designed to elongate through the use of metal sheets.

Construction Sequence:

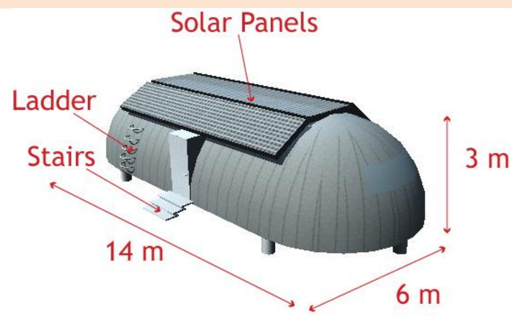


Phase 1: The undeployed base is shipped to Mars in its cargo container.



Phase 2: The floor of the base is set up. The support columns keep the base clean.

Phase 3: The pieces of the base are assembled and locked together.



Phase 4: The exterior of the base is completed, and interior configurations are set up. A ladder allows the settlers to clean the dust off the solar panels.

Table 2.5.1 Prefabricated Base Construction

3.0

Operations + Infrastructure

Section 3: Operations + Infrastructure

In providing the best facilities for new settlers on Aresam, Northdonning Heedwell will carefully take into account the smooth and concerted operation of all systems. It is our highest priority to ensure that construction and operation take place seamlessly, enabling and freeing residents to work and live comfortable, safe lives.

3.1 Orbital Specifications and Materials

3.1.1 Orbital Location and Specifications

Aresam will be situated in a near-polar, sun-synchronous orbit at 94 degrees inclination and between 390 km (periapsis) and 450 km (apoapsis) altitude from the Mars surface. Several considerations have been taken into account in selecting this orbit. Firstly, from the rotation of Mars and the orbit of the settlement, Aresam will cover all of Mars's surface over the course of its orbit, thus allowing for a wide range of possible locations to set up prefabricated bases, mine, and conduct research. In addition, the orbital altitude, somewhat higher than those of other satellites currently orbiting Mars, is near enough to the surface to allow for operations to be conducted between the surface and the settlement while being high enough that atmospheric drag is greatly reduced, thus reducing the need for propulsion to keep the settlement in orbit. The sun-synchronous orbit allows for near-constant lighting, ideal to maintain energy and to ease external operations on the settlement. Finally, the polar orbit is ideal for communication with Earth, as Mars will not interfere with signals as long as the orbit is sun-synchronous.

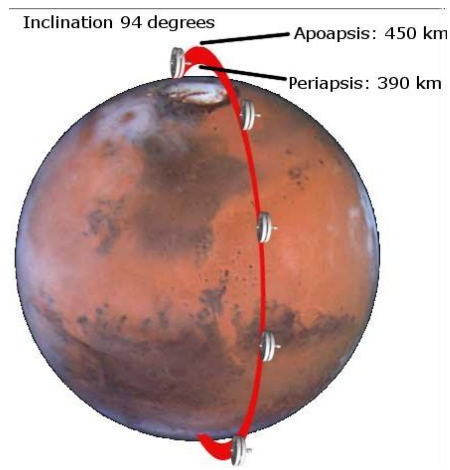


Figure 3.1.1 Orbital Diagram

3.1.2 Sources and Transportation of Construction Materials and Equipment

Listed below are materials to be used in different aspects of Aresam operations. Raw materials, once acquired from the source, will generally be processed on Aresam before use, except in the case of materials required for construction, which will be processed on Aresam as repair material after construction is complete. Northdonning Heedwell has specifically ensured that a majority of materials comes from the Martian moons to facilitate production and minimize costs.

Commercial spacecraft include various ships operated from Earth, from other colonies, and from Aresam that may be developed privately or delegated to Northdonning Heedwell.

Processed material	**Source of *raw* material**	**Transportation**	**Storage**
	Construction & Structural		
6061-T6 Aluminum Alloy	Bellevistat; Phobos & Deimos	Commercial spacecraft	*Graff* manufacturing sphere
Steel Alloy Grade 18KhGNMFR			
	Radiation Protection		
*Fused Silica Glass**	Phobos & Deimos	MoonMiner	*Graff* sphere
*Silica Aerogel**			Central axis
Martian Regolith	Mars	MoonMiner	Used directly and not stored extensively due to dust contamination
Demron cloth	Earth	Commercial spacecraft	Central axis
Ra-guard	Earth		Central axis

Operations			
*Electronics**	Phobos & Deimos	MoonMiner	Central axis and *Graff*
*Silicon solar cells**			*Pascal* port and *Graff*
Polyethylene (solid & foam)	Alexandriat	Commercial spacecraft	Central axis
Dinitrogen tetroxide	Earth		*Pascal* port and *Graff* manufacturing sphere
Helium-3			
Deuterium			
Hydrazine			

Table 3.1.1 Sources, Transportation, and Storage of Materials

3.2 Settlement Infrastructure

3.2.1 Atmosphere, Climate, and Weather Control

To provide for the health of the residents, as well as for psychological comfort, Aresam's air composition will be similar to that of Earth's. Trace elements have been eliminated from Aresam's atmosphere for cost and convenience. High levels of carbon dioxide will be prevented from accumulating by means of the Sabatier reaction alumina catalyst reactor: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. The methane will be broken down into solid carbon and $2H_2$; the hydrogen will be reused in the reaction. The water will be electrolyzed for the regeneration of oxygen. This cycle will provide efficient recycling of gases as well as generate some of the required water for the settlement.

Aresam will experience "seasons" through gradual changes in temperature. Though these changes will be slight to maintain stability for Aresam's equipment, they will psychologically provide a familiar Earth-like environment. The temperatures will span from 25°C in the summer, to 20°C in the fall, then 15°C in the winter before returning to 20°C in the spring. The seasons will be the same as Earth's three-month cycles to further increase familiarity for the residents: June-August for summer, September-November for fall, December-February for winter, and March-May for spring.

To further simulate an Earth-like environment and provide familiarity for residents, artificial rain will fall on areas where humidity has increased. Water vapor will be collected on condensation plates above the communities and deposited in pressurized water containers; hidden sprinklers throughout the facility will then spray this on the residences.

3.2.2 Food Production

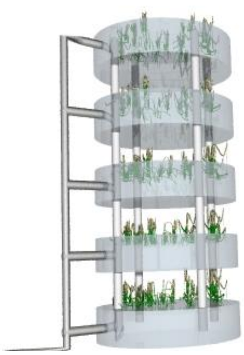


Figure 3.2.1 Aeroponic Tiers

Food Growth

The majority of plant food on Aresam will be grown using aeroponics technology. Aeroponics is the optimal growing option, over hydroponics and traditional growing methods. It will allow for maximized production of plants, without the expense and problems of water in hydroponics, or of transporting soil from Earth. Plants will be grown in a large, controlled tier structures. These tiers will allow for the propagation of nutrient-filled mist through many plants at once, saving water and surface area. Finally, lighting for the plants will be provided for by low pressure sodium lamps. The growth of plants will largely be automated, with regular inspections for quality.

Food Harvesting

Plant-derived consumables will be harvested by an automated system and transported to a processing unit for storage and distribution.

Food Storing

Surplus food will be freeze-dried, vacuum-sealed, and stored in a one of several large food storage grids. The grid will have many compartments in which to keep stored food at programmed conditions, and a computerized system can be used to find a particular

Figure 3.2.2 Food Storage Grid

compartment to retrieve food. Food sufficient for 10 months will be stored in the central axis of the settlement. Furthermore, food sufficient for 4 months will be stored in the community centers, as well as the industrial section.

Food Packaging

Food for immediate distribution will not be freeze-dried nor vacuum-sealed, but packaged in reusable polyethylene containers. Liquids will also be packaged in reusable pouches. Used containers and pouches will be deposited in bins located throughout the settlement and collected every 2 days for reuse.

Food Delivery

After being packaged, food will be delivered to restaurants and grocery stores in the freight subway system described in Section 3.2.7. In turn, restaurants and grocery stores can then distribute food out to those who require it.

Food Selling

Food can be bought individually in grocery stores and restaurants. To minimize food waste, people will only be able to purchase a limited amount of food. Should they need to purchase larger amounts of food for any event, they may apply for this at a community center. Food that has been on sale for more than 3 days shall be freeze-dried and vacuum-sealed for storage. In addition, residents' food intake may be monitored if the resident shows signs of eating habits that may prove detrimental to health on the settlement.

3.2.3 Electrical Power Generation

Initially, power for Aresam will be produced by a nuclear power plant on the surface of Mars. After solar power has been established, the nuclear power plant will serve as a backup until the colonization of Mars begins. The solar panels will be made of multi-junction photovoltaic cells with a conversion efficiency of approximately 40%. These cells consist of several thin layers which allow the cell to absorb more of the solar spectrum. The intensity of sunlight around Mars is 0.431 times as strong as around Earth. Therefore, solar powered satellites will generate power from Earth's orbit, then beam it to the settlement through microwaves. For each 1 by 1 meter solar panels on these satellites, 3.6 kilowatts will be produced per hour. Additionally, backup satellites will be stationed in Mars's orbit, producing 1.6 kilowatts per hour. Surplus electrical energy will be stored in lithium air batteries, which have a higher energy density than lithium ion batteries, due to lighter cathodes and the large amount of oxygen available in the atmosphere. Power will be distributed around the settlement, with battery backups in each major component; a power failure in any one section will activate its battery, providing energy for up to one week.

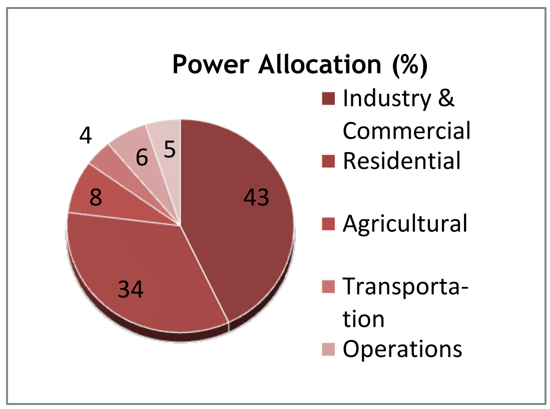


Figure 3.2.3 Power Allocation

3.2.4 Water Management

Water Requirements

10.76 Liters of water per person per day will be provided to the citizens of Aresam. For a settlement of 27,000 people, the total amount of required water will be 247,480 Liters. The total amount of water on Aresam will be 500,000 Liters, taking into account the needs of food production and other functions. Water will be transported from Alexandriat, Bellevistat, and Columbiat. Approximately 24,000 Liters of water will be taken from each settlement during each of Aresam's building phases, amounting to 72,000 Liters of water per phase. Approximately 90% of the water will be recycled, leaving 450,000 Liters of usable water. Every four months, water will be brought in from Bellevistat, Alexandriat, and Columbiat to replenish the water supply.

Figure 3.2.4 Water Storage Tank

Water Storage

Water will be stored in a total of fifty tanks placed throughout the settlement. Each water storage tank will be able to hold 10,000 Liters of water. There will be 12 storage tanks in the central axis (120,000 liters), 22 storage tanks between the two residential tori sectors (220,000 liters), 12 storage tanks in the manufacturing sphere (120,000 liters), and 4 storage tanks in the port (40,000 liters).

3.2.5 Household and Industrial Solid Waste Management

The WWTC (Waste and Water Treatment Center) will be located in the central axis for convenience. Waste will undergo anaerobic digestion, where it will be broken down into digestate, waste water, and biogas. The nutrient-rich digestate will be used in the mist used for aeroponics. The waste water will undergo purification and further processing for recycling. The biogas will be composed of methane, carbon dioxide, nitrogen, hydrogen, hydrogen sulfide, and oxygen. The CH4 will be broken down into carbon and $2H_2$, while the carbon dioxide will be broken down by means of the Sabatier reaction in an alumina catalyst reactor: $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$. The hydrogen sulfide will undergo a chemical reaction with potassium at high temperatures to produce hydrogen.

3.2.6 Internal and External Communication

Internal Communications System

Internal Communications will be divided into three major sections: public communication, individual communications, and data networking. Public communication will take place via intercoms placed throughout the settlement. Announcements using the intercoms can be made from control stations located in each torus, as well as the central axis and docking port, by anyone with system developers/technicians authorization or higher (See section 5.0.3). Announcements can be isolated to certain sections of the settlement, should there be a situation requiring so. Individual communications will take place through the Amicus (See section 5.3.1). Communications will be made through voIP (voice over IP), over wireless networks throughout the settlement. Data networking will be provided by a compact fiber optic system. Fiber optics are suited for processing large amounts of data, efficiently providing fast transfer speeds.

External Communications System

Communication to and from Earth, other satellites, and space colonies will take place via lasers. Lasers provide the highest transfer speeds for long-range communication and do not utilize excessive energy. In the event of a failure in the laser communication system, backup radio satellites will automatically begin relaying information. In order to deal with time delays between Earth and the settlement, a "time telescope" technique will be employed. While the lasers used in communications cannot be sped up, the amount of information they carry can be increased. The length of each laser pulse will be shrunk into $1/27^{th}$ its original size by 2 lens working together like in a simple telescope. A similar system on the receiving end will then decompress the data into a form regular systems can read. Unfortunately, this system cannot be employed should there be a failure in laser communications. Therefore, radio communications will still have an approximate half-hour of delay. The three power generating satellites orbiting Mars will host the laser communication systems, as well as the backup radio systems.

3.2.7 Internal Transportation

All vehicles will use *electrorheological fluid* for braking and shock absorbing purposes. The fluid will create an effective brake, especially in the event of an emergency failure of the magnetic fields controlling the vehicles; sensors will activate an electric field within any vehicle and apply sufficient compressive pressure in order to turn the fluid viscous and stop the vehicle.

The main form of transportation within Columbiat will be *walking* in order to ensure that the population gets a sufficient amount of exercise without needing to be monitored. In the event that a person is unable to walk, wheelchairs and bicycles will be available to them throughout the settlement.

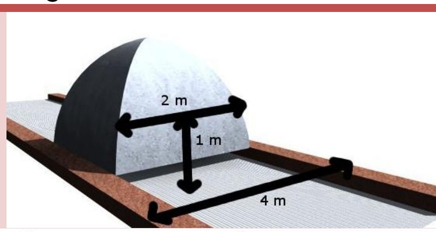
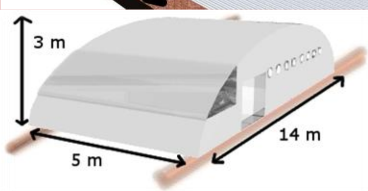
Vehicle Name	Image	Details
Magnetic Railway Pod (MRP)		Pods will be used to transport goods as well as people between the central axis and tori. The gravity in the pods can be adjusted to meet the needs of the user: cargo will use lower gravity than people for ease of transport. Pods will use magnetic levitation technology to carry its passengers.
Freight Subway System		The freight subways will be used to carry goods and large cargo beneath the pedestrian floor of the tori and manufacturing sphere. The freight subways facilitate the transfer of large goods and food.

Table 3.2.1 Internal Transportation

3.2.8 Day-Night Cycle Provisions

LED lights will be placed on the ceilings of residential areas and will be managed from the central axis. They will be programmed to brighten in the morning, and then begin to dim in early afternoon, finally ending in near-total darkness in the evening. The cycle will operate on the basis of an Earth day to facilitate communications, as Aresam is not in a Mars-synchronous orbit and thus has no need to follow the Martian day. Different schedules will be used for different seasons to increase psychological comfort for the residents- in the summer, the lights will brighten from 5 AM until 3 PM, then darken until 7 PM; in the fall, the lights will brighten from 6 AM until 2 PM, then darken until 6 PM; in the winter, the lights will brighten from 7 AM until 1 PM, then darken until 5 PM; and in the spring, the lights will again brighten from 6 AM until 2 PM, then darken until 6 PM. In between each season, one week's time will be used to make a smooth, slow transition to the next season's time schedule. At nighttime stars will be projected, and the moon that will be projected will follow the phases of Earth's moon.

3.2.9 Commodity Contingency Plans

Although agricultural areas on Aresam will be carefully isolated from the remainder of the settlement to prevent any possible blight, we acknowledge the possibility of such a disaster on the settlement. As described in section 3.2.2, food sufficient for up to ten months will be stored in freeze-dried form in food storage grids in the central axis. As soon as agricultural operations commence, this store will be built up; in addition, any surplus goods will be stored in food storage grids in communities in the event of a failure in the central axis.

3.3 Construction Machinery and Equipment

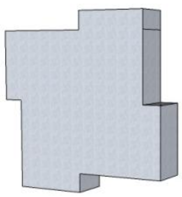
3.3.1 Hull Assembly

Figure 3.3.1 Hull Assembler

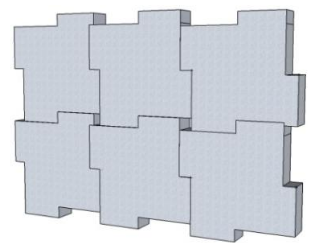
The hull will be assembled first in a skeletal structure to provide a foundation for the components to be added. Hull assembly robots will then travel along the structure and piece together the hull. Each hull assembly robot is specialized for a specific portion of the hull: one may add windows; one may add a regular hull exterior piece. Portions of the skeletal structure are encoded so that a hull assembly robot can "read" it with a laser and identify precisely what type of hull piece belongs there. Each hull assembly robot is stocked with a supply of the hull piece it is specialized for: for example, a window assembly robot would be stocked with 50 window pieces. The robot can then drop and lock the piece onto the structure, moving on to make way for more robots.

The hull interior will also be finished robotically. The layers of radiation protection will be "applied" to the surface in a staggered series of panels that ensures both rapid assembly and adequate insulation and redundancy. The gaps in the panels will be filled with insulation, although they are already compensated for by the staggered layout.

3.3.2 Interior Building Assembly



The exteriors of buildings are assembled via a framework of interlocking panels. These panels allow for quick, stable assembly of large structures and rapid replacement of parts in the event of damage or wear. Panels are first assembled into walls and then erected and interlocked to form a building. Thicker panels can be fitted in horizontally to form floors and ceilings. The small spaces in the panels can be either insulated or used as passages for electricity and communications systems. A team of robots then takes over the assembly: one robot each for power, water, roofing and flooring, furniture, detailing, and other specialized needs (for example, an equipment robot for a theater). Groups of these robots can then be called for repairs in the event that they are required.



Figures 3.3.2 Interlocking Panels

Research facilities are designed and built to the specifications of the researcher, as are other specialized buildings.

3.3.3 Transportation Assembly

Railway systems in the settlement will be assembled by a machine. It will be stocked with a supply of rail segments and will lay them out along the appropriate pathway, and will have the capability of initiating the magnetic levitation system in the rails by inducing their magnetic polarity and alternating the polarity on each rail segment.

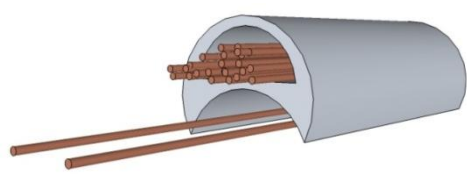


Figure 3.3.3 Rail Assembler

Vehicles will be separately assembled and brought to the railway line once the rails are assembled.

3.4 Materials Harvesting and Refining

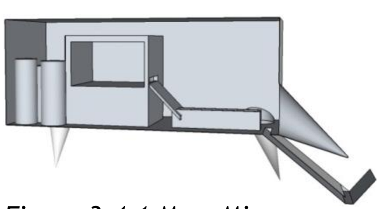


Figure 3.4.1 MoonMiner

Materials will be harvested from Phobos and Deimos via a system of large harvesting machines dubbed MoonMiners. A ship will transport up to five MoonMiners at a time to a moon and leave them there to harvest materials.

Each MoonMiner is equipped with the capability to sort the materials it harvests and refine them to a certain extent. The MoonMiner will first implant itself in the lunar surface on retractable 'feet,' and then extend a drill into a region of the surface. A separate component will then be used to collect the materials from the drilled area and transfer it into the collection compartment of the MoonMiner. There, automated technology will be used to sift and sort through the materials, comparing them to a catalog of known materials. Hazardous materials will be returned to the lunar surface; unknown materials will be quarantined for research purposes. Once the materials are identified and sorted, they will proceed one at a time into a miniature preliminary refinery, in which the materials are carefully liquefied if their melting point is low enough, or otherwise simply ground down into a powder that can then be solidified by pressure.

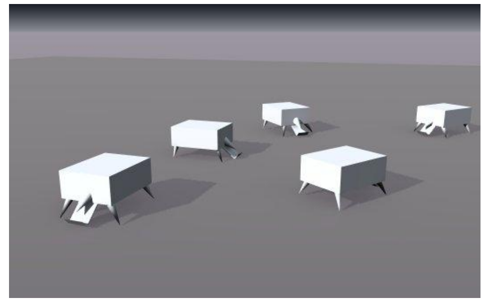


Figure 3.4.2 MoonMiners on Phobos

Once the sorting and refining procedure is complete, a ship will return to the moon to collect the materials. A MoonMiner will remain on a moon until it is damaged, at which point the next materials collection ship will take it back to be repaired and replace it in the meantime with one of ten reserve MoonMiners. The materials will be carefully packaged in the ship so as to quarantine them before they reach the settlement, only to be opened in a clean room in the manufacturing sphere by trained specialists. There, materials will be refined once more under high temperature and pressure conditions.

3.5 Prefabricated Base Systems Specifications

3.5.1 Air Supply

The initial atmospheric air will be contained in tanks in the storage container for the base. As soon as the base is fully assembled and sealed, the atmosphere will be triggered to begin filling and stop at 0.7 atm. Emergency air to fill the base once over will be included in the base container. Air filtration will occur through a unit attached to the base, and contaminants will be collected rather than vented to the atmosphere.

3.5.2 Food Supply

Enough freeze-dried food to provide for 40 days will be provided. Non-freeze-dried, nonperishable food that would last for 10 days will also be provided in the event of a water shortage. Food will be packaged in pre-made meals to ensure proper nutrition and a balanced diet while on the base.

3.5.3 Power Supply

Power will be provided through battery packs located just outside the base (in case of a failure or leak). The battery packs (arrays of cells) will be able to provide enough power to supply the base for two months. Once the base is set up, however, transmission of solar power from the main settlement will be initiated, so that the battery packs will then become emergency backup power.

3.5.4 Water Supply

Water for 40 days will be supplied with the base in one miniature version of a water storage tank. Additional water, enough for one week, will be sent to the base every five days. Flexible water pipes will allow pipes to be pre-connected and simply unfold as the base is set up.

3.5.5 Waste Management

Waste will be collected rather than vented and will be disposed of periodically. Like the mining pods, waste units will contain miniature processing plants so that water can be purified and waste can be incinerated. In the event that the processing unit fails, the waste unit can be sealed off and replaced with another functioning one (provided with the base), and the sealed unit will be sent to Aresam for processing and replacement.

4.0

human factors

Section 4: Human Factors

A combination of Earth-like qualities and outer-space fantasticality, communities on Aresam are intended to remind inhabitants of their native environment while providing the exotic experience of living in a space settlement. We at Northdonning Heedwell are committed to providing our inhabitants with quality comfort and superior services.

4.1 Community Design and Amenities

4.1.1 Community Layout and Facilities

From large, spacious shopping malls to high-tech gaming centers and well-equipped sports facilities, Aresam provides many – if not all – of Earth's most desired amenities and services. Communities will be built around a central business and entertainment district.

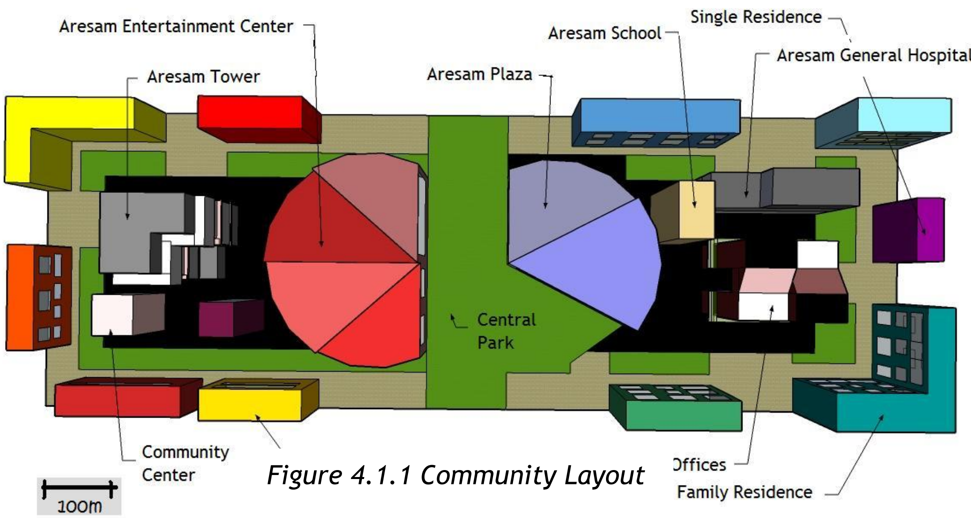


Figure 4.1.1 Community Layout

The business zone will consist of two 5-level offices: Aresam Tower and Aresam Office. The bank will occupy the entire first floor of Aresam Tower, with the security deposit on the 5th level of the same building. Up to two large corporations will fill up the 2nd and 3rd floors. A courtroom will also be located on the 4th floor of Aresam Tower. Smaller businesses will be located in the adjacent Aresam Office. Aresam General Hospital, a three-tiered structure, will also be in this sector, along with the Security Headquarters and Aresam Primary and Secondary School. Of course, other general stores will occupy the remaining space in this central district.

The entertainment sector will have – along with a scattered handful of other outlet stores – two primary buildings: the shopping mall and the colossal entertainment center. Mirroring the shopping malls on Earth, the three-story, futuristic Aresam Plaza will offer a wide range of retail stores, selling items from designer apparel and collectibles to home goods and electronics. A portion of the third floor will be dedicated to fine dining opportunities and other restaurants to satisfy the superior tastes of our connoisseurs.

The Aresam Entertainment Center (AEC) is a 5-story structure dedicated to exercise and entertainment. The sports facility will be located in the south and east wings of the building, providing access to various indoor courts, as well as a well-equipped fitness center. The west wing will house a stage for the performing arts. This stage will rotate through performances of plays, musicals, concerts, and dances. The Aresam Natural History Museum and Aresam Public Library will also be in the AEC's west wing to please the intellectually-inclined. A high-tech arcade featuring laser tag and 3 virtual reality gaming consoles will be situated in the north wing of the building. Movie-goers will also be satisfied with the 4 large movie theaters in this north wing.

Residential buildings will be placed around this central district. A large park will run through the center of the community. The green belt will stretch from one side of the settlement to the other, giving residents an unobstructed 0.8 mile line of sight.

Extensive paths and roads will allow access to all parts of the community. 2% of the community will be designated for these paths and roads. Additional spacing between residential buildings will provide opportunities for expansion should the population of our settlement increase.

4.1.2 Major Consumables

Type of Consumable	**Amount per year * for all (R) & (T)**	
	Residential (R)	Transient (T)
Food	3,193,750 kg/yr	79,844 kg/yr
Water	126,107,500 kg/yr	3,152,688kg/yr
Oxygen	3,832,500 kg/yr	95,812kg/yr
Hygiene Product	876,000 kg/yr	21,900 kg/yr
Pharmaceuticals	73,000kg/yr	1,825kg/yr
Paper Products*	183,600 kg/yr	4,590kg/yr
Clothing*	8025 articles/yr	386 articles/yr
Shoes*	5700 pairs/yr	274 pairs/yr
Electronics	50,000 items/yr	2400 items/year
Kitchen Appliances	3262 items/yr	82 items/yr
Furniture	130,000 items/yr	6375 items/yr
Research Materials*	10,000 items/yr	1000 items/yr

*Figures may vary. Figures are estimates

Table 4.1.1 Major Consumables

Table *4.1.1* details the annual quantities of major consumables on Aresam. Many items, including clothing and research materials, will be dependent upon the needs of our residents. General stores located in the central district will be responsible for the distribution of consumer goods.

4.2 Home Design

4.2.1 Typical Residences

To accommodate the wide variety of residents, Aresam will offer multiple plans in three basic categories: single residences, double residences, and family residences. The single residences are to accommodate those who prefer to live alone. These dormitory-like residences range from 800-1100 square feet. For married couples without children or those who prefer to have a roommate, the double residences provide larger square footage – 1200 to 1500 square feet. For a family of 3 or more, our family residences will offer floor plans of 1600 to 2000 square feet. Each Aresam community will include 3 sections of single residences, 2 sections of double residences, and 1 section of family residences, with each section compiled of 4 or 5 residential complexes. These residential complexes will be interspersed around the community to support the intermingling of different types of people.

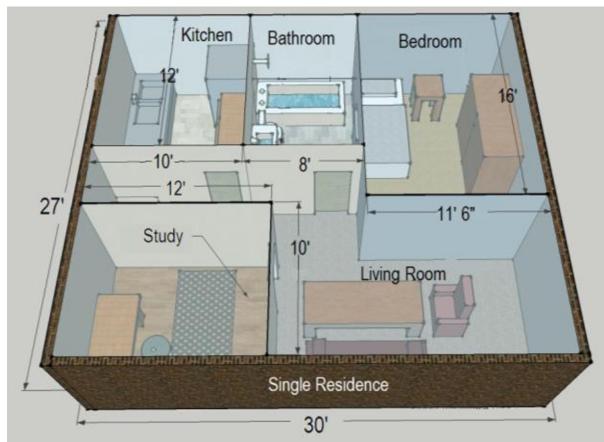


Figure 4.2.1 Single Residence I

For those who enjoy more privacy, we also offer custom housing, which are essentially single family houses built apart from the regular residential complexes. These houses will cost more than our regular residences. Each community will have a sector designed primarily for these houses.

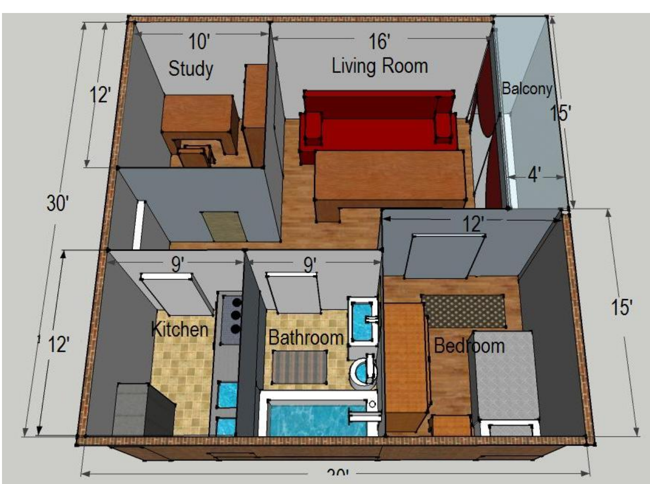


Figure 4.2.2 Single Residence II

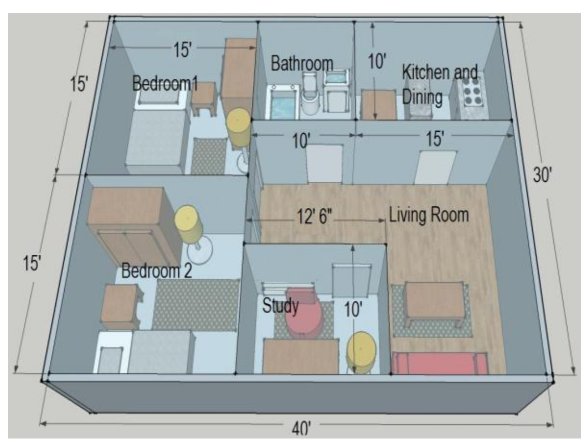


Figure 4.2.3 Double Residence

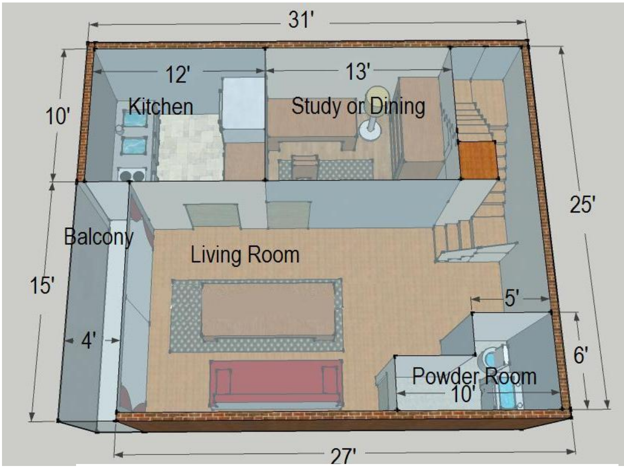


Figure 4.2.4 Family Residence Floor 1

Figure 4.2.5 Family Residence Floor 2

4.2.2 Furniture

To create an outer space atmosphere, Aresam will be offering unique “Mars-based” furniture designs. For the more traditional residents, Aresam will also provide typical earth-like furniture. Furniture will be supplied by typical Earth furniture stores, such as IKEA. In addition, Aresam Furniture Company will be the supplier of furniture from our Mars line, custom-made from materials from Phobos and Deimos.

4.3 Activity in Microgravity and Unpressurized Volumes

4.3.1 Human Travel in Microgravity Areas

Figure 4.3.1 Foot Rail

Aresam will implement various measures to ensure human safety in microgravity areas.

When walking on the exterior of the space settlement, humans and robots will be attached to cable harnesses (tethers) to prevent them from drifting away into space. Humans must also communicate with the space settlement twice every hour to relay their status to the settlement’s control crew. Humans participating in exterior maintenance work must be in a spacesuit at all times.

Foot rails will be placed on all accessible exterior areas of the settlement as another safety measure and to serve as a sort of visual map for workers on the exterior of the settlement. Workers will be asked to wear magnetic shoes to prevent detachment from the magnetic rails. Maintenance robots will also be magnetically attached to these rail lines. Most maintenance work will be conducted by robots.

4.3.2 Spacesuit Design

Donning Procedure:

1) Disassemble space suit (refer to suit storage below)
2) Reduce pressure in airlock antechamber to .7 atmosphere
3) .5 hour of 100% oxygen pre-breathing to reduce nitrogen concentration in blood and tissues
4) Put on Maximum Absorption Garment (MAG)
5) Put on Liquid Cooling and Ventilation Garment (LCVG)
6) Attach EMV Electrical Harness (EEH) to inside of Hard Upper Torso (HUT)
7) Attach arms of suit to HUT
8) Connect Display and Control Module (attached to HUT arm) to EEH and Primary Life Support System (PLSS-pre-

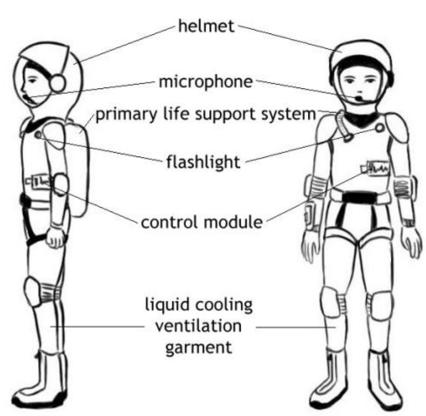


Figure 4.3.2 Spacesuit Design

attached to back of HUT)
9) Coat inside of helmet with anti-fog spray; attach Extravehicular Visor Assembly (EVA) to helmet.
10) Attach the in-suit drinking bag (IDB) to its location within the HUT
11) Connect communications carrier assembly (CCA) to the EEH
12) Put on the lower torso assembly (LTA)
13) Establish radio contact with base and ensure functionality of EEH and PLSS
14) Put on HUT
15) Attach tubes of LCVG to PLSS
16) Attach EEH to PLSS
17) Connect LTA to HUT
18) Don CCA
19) Put on comfort gloves, secure oxygen mask over face, lock on helmet (oxygen flow should commence once helmet is properly secured)
20) Lock on outer gloves
21) Robot will check suit to ensure donning has been performed correctly; robot will also assess functionality of EEH, PLSS, CCA and other suit systems
22) Enter airlock and reduce pressure in airlock to .3 atmosphere and perform further inspection for leaks in suit

Doffing Procedure:
1) Upon entering airlock, wait for pressure to be raised to .55 atm (indicated by a chime)
2) As astronaut removes suit, pressure will steadily increase to the normal pressure in the settlement. This is done to reduce the chance of decompression sickness.
3) Remove Outer gloves, comfort gloves, helmet; disconnect EVA from helmet
4) Detach CCA from EEH and remove it
5) Detach LTA from HUT
6) Disconnect EEH from PLSS
7) Disconnect LCVG from PLSS
8) Remove HUT
9) Detach EEH from inside of HUT
10) Remove IDB from inside of HUT
11) Step out of LTA
12) Remove LCVG
13) Remove and dispose of maximum absorption garment (MAG)
14) Reattach helmet, LTA and HUT to prepare suit for stowage
15) Leave airlock
16) Return suit equipment to personnel for stowage
17) Report to on-site med-bay for medical diagnostic

The suit is comprised of nylon tricoat, spandex, urethane and neoprene coated nylon, Dacron, Mylar, Gortex, Kevlar, Nomex, and Demron to ensure sound protection for the wearer while providing comfort and flexibility.

The mixture used in the space suit air tanks will be a heliox mixture (79% helium, 21% oxygen) to minimize potential effects of oxygen narcosis and decompression sickness. Though 100% oxygen has been used in the past, the potential dangers of respiring pure oxygen, such as neurological damage, cardiac damage, potential alveolar collapse, and potential seizures outweigh its benefits.

The pressure within the suit will be about .55 atmospheres of pressure to allow the astronaut full mobility while inside. However, to ensure a proper A-a gradient, the astronaut will be wearing an oxygen mask around his nose and mouth that will be attached to the EEH (EMU Electrical Harness). The mask will alternately pressurize to one atmosphere during inhalation and depressurize to .5 atmospheres during expiration (the mask's connection to the EEH will allow it to synchronize its cycle of compression and decompression to the astronaut's respiration rate) to ensure the astronaut has an alveolar gas pressure similar to the one he would have were he at sea level on Earth, which will allow for maximum efficiency of respiration.

Space Suit Storage

Each individual space suit will be stored in an individual cell (slightly larger than a phone booth) that is attached to an axis with the ability to rotate. The suit will be stored with the HUT, Helmet, LTA and gloves all attached together (external components of the suit will be stored fully assembled), with the EEH and LCVG hanging on the side walls of the cell. The MAG, CCA, in-suit drinking bag, and comfort gloves will be stored in a footlocker against the back wall of the cell. The complete assembly of the outer layer of the suit during storage will make it more expedient to either remove the suit from or return the suit to storage. The placement of the individual cells on a rotating axis conserves space and expedites the removal/return of multiple suits from/to storage.

4.3.3 Airlock Design

Airlock

The door to the airlock will be opened upon the completion of the spacesuit donning process. A robot will proceed to inspect the suit once again to ensure the absence of external damage and leaks. When the examination is completed and no damage is detected, the robot will sound an alarm (presumably a chime) and air will be slowly removed from the airlock via the air vents until a pressure of 0.3 atmospheres is reached. A robot will check the suit for a final time before the worker leaves. Should the suit pass examination, the air vent will proceed to remove all the air from the airlock. The airlock will then be tested to ensure that all air has been withdrawn. At this point, the second door will open and the worker may leave.

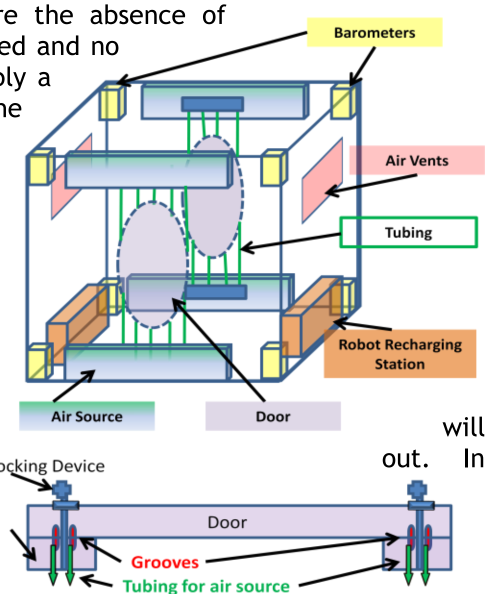


Figure 4.3.3 Airlock Diagram

Airlock Doors

To prevent the unnecessary loss of air, the airlocks will have specially designed doors to prevent air from leaking out. In addition to regular locking mechanisms, the door will encompass a series of grooves with inflatable plastic tubing. Upon the closing of the door, an automated system will lock the door. At this time, air will be introduced into the plastic tubing (via an air source) until an airtight seal is formed in the grooves. This would prevent air from leaking through the tiny gap between the door and the wall. The door will also be rounded to minimize the stress induced by corners of rectangular doors.

4.4 Demographic Shifts

The following are projected demographic trends on Aresam over the first two decades of its operation based on economic projections, changing demographics, and possible trends on Earth. Since housing design is largely dependent upon the individual wishes of the colonist, and houses can easily be modified with the interlocking panel system in section 3.3, the settlement will easily adapt to changes.

4.4.1 Racial Trends

Years 1-5

Race	Percent (%)
White	70.0
Black/African American	12.0
Hispanic/Latino	12.0
Other Race	6.0

Years 6-10

Race	Percent (%)
White	68.8
Black/African American	11.6
Hispanic/Latino	11.8
Asian	4.8
Other Race	3.0

Years 11-15

Race	Percent (%)
White	67.2
Black/African American	11.2
Hispanic/Latino	11.5
Asian	4.0
American Indian/Alaska Native	1.0
Other Race	5.1

Years 16-20

Race	Percent (%)
White	66.8
Black/African American	10.9
Hispanic/Latino	11.1
Asian	3.2
American Indian/Alaska Native	0.9
Other Race	7.1

Tables 4.4.1 Racial Trends

4.4.2 Generational Trends

Years 1-5

Category	Percent (%)
Married Adults	40.0
Single Men	35.0
Single Women	23.0
Children Under 18	2.0

Years 6-10

Category	Percent (%)
Married Adults	41.0
Single Men	32.6
Single Women	25.2
Children Under 18	1.2

Years 11-15

Category	Percent (%)
Married Adults	41.2
Single Men	30.6
Single Women	27.2
Children Under 18	1.0

Years 16-20:

Years 16-20

Category	Percent (%)
Married Adults	41.8
Single Men	28.5
Single Women	28.0
Children Under 18	1.7

Tables 4.4.2 Generational Trends

4.5 Prefabricated Base Interior

The interior of the base will be divided in four main categories: Research, Storage, Communication, and Living Area. The two half-domes on either side of the base will be reserved for research and communication. Storage and living area will be interlocked to ease the access to stored fuel, water, food, and other essentials. Although the quarters are rather small and the crew will only be provided freeze-dried foods, researchers should be able to live nearly as comfortably as residents on Aresam.

Figure 4.5.1 Prefabricated Base Interior

5.0

automation design + services

Section 5: Automation Design + Services

By virtue of innovation and creativity, automation on Aresam promises to push the settlement to the limits of technological advancement.

5.0.1 Types and Numbers of Computers

Name	Description	Specifications
Amicus	Using FOLED Screen technology, the Amicus is the personal device for each member of the space settlement. It has IM capabilities and wireless connectivity to UNet. It also has access to music, personal data, and videos. From the Amicus device, users can adjust settings to their homes.	**4" by 2.5" with screen expandable to 6"**
SmartHome	This human user in home interface is especially helpful for members of the settlement. It uses an Internet Zero design which enables communication between appliances in the home as well as a system which adjusts to specific user settings using an advanced learning system. It analyzes outgoing and ingoing data to discover and anticipate user preferences. Components: Storage areas, Entertainment System, Appliances, Communication of home with Amicus	**Integrated within residences, hidden within furniture**
Business PC's	Built with especially high memory capabilities, these systems come preloaded with applications for accounting and inventory management.	**8 TB RAM 15 PB HD 2.34 THz**
Research PC's	These are built with high processing and memory capabilities. They are filled with pre-loaded applications which help for data analysis and management.	**16 TB RAM 20 PB HD 3.64 THz**
Entertainment PC's	Entertainment PC's are built with High Definition 30 inch touch screens and have access to the entertainment system. The settlement entertainment system includes various movies, video games and music. There is HD Surround Sound Audio available or wireless headphones.	**8 TB RAM 10 PB HD 2.95 THz 16.2 GHz (GPU)**

Table 5.0.1 Types and Numbers of Computers

5.0.2 User Hierarchy in System

Type of User	Description	Numbers
Network Administrators	• Installing and Upgrading the existing user networks • Allocating System storage options	10
Database Admin	• In case of a system failure, we revert to manual oversight, Gives manual control of robots to the technicians	10
Communications Operations Admin	• Oversees the safeguarding of information being sent; works to solve issues with encryption or communication failures • In case of communication breach, manually overrides this system and activates backup systems and implements	10
System Developers/ Technicians	• Look over the problems and create fixes • Manage upkeep of computing networks and systems throughout the settlement • Lower level administrators	100
Advanced User	• Assigned to certain residential areas and monitor local database user in that area • Report issues or breaches to administrators or the system	5 to 10 per hub

	developers	
Basic User	• Can access and save personal data on the system	20,000+

Table 5.0.2 User Hierarchies

5.1 Automation for Construction

The robotics for onsite construction on Aresam is both sophisticated and versatile. With the use of features including the omnitool, the construction robots are designed for efficiency and ease of maintenance. There are two essential classes of robots on the settlement: interior and exterior finishing bots, with two main subsets consisting of large scale and small scale construction.

5.1.1 Required Automated Robots

Robot Name (Dimensions)	Functions
THsu Construction Robot (Arms Extendable to 5m, Height: 2m, Width: 5m)	This robot's main functions including laying of the sheets of metal lining for exterior and interior structures. The robot is equipped a mechanical arms with the apparatus for welding, and clamps for carrying. This robot is one of the primary construction robots on the settlement. There is a caulking gun, a cutter, a riveter, and a soldering arm on the robot, integrated into the omnitool.
The C Class	These are the robots which deal with the overall construction of the exterior and interior components.
C-1 Interior Finishing Bot (Height: 2m, Width 1m, Length 0.75m)	Equipped with an omnitool with welder, mechanical arm with 360 degree rotational hand, rivet screwdriver and knife. They will be equipped with a vacuum in the other hand. Third hand is arm attached to storage area, made for identifying rubble and waste and placing in storage pack.
C-2 Exterior Finishing Bot (Height: 2m, Width 1m, Length 1.5m)	External robot. Equipped with an omnitool which includes a welder, mechanical arm with 360 degree rotational hand, drill, and laser cutters. The key defining feature is self identification of function. Each robot has the ability to identify its specific function and subsequently execute it.
The R Class	This class of robots deals with the construction of components which comprise the residential structures within the settlement.
R-1 Residential Construction Bot (Height: Extended to 5m, Width: 2m, Length:2m)	There is an elaborate grid system in place along which the construction robots travel while constructing the specific housing. Each mechanical arm of these robots include a 360 degree rotational movement capacity as well as interchangeable parts with the R-2 finishing bot for ease of maintenance
R-2 Residential Finishing Bot (Height: 1m, Width: 1m, Length: 1m)	Made for in home installation of appliances and electronics, These robots are equipped with the ability to install already assembled sections of the interior of residences. Users have the ability to send instructions to this robot in terms of where in the residence it should install.
The S Class	These are highly versatile, smaller robots which deal with the smaller fixes and repairs. With the implementation of the omnitool, they are easy to maintain and repair.
S-2 Exterior Finishing Bot (Height: 1m, Width: 1m, Length: 0.5m)	This is an external robot. Equipped with an omnitool that has a welder, mechanical arm with 360 degree rotational hand, drill, and laser cutters.
S-3 Exterior Assembly Bot (Height: 1m, Width:	It is equipped with 6 arms, adhesive releasing nozzles, storage capacity and solar panels. The main functions of this robot include securing pillars

0.5m, Length: 0.5m)	and dome assembly.

Table 5.1.1 Construction Automation

5.1.2 Omnitool

Figure 5.1.1 Omnitool

An **omnitool** is an innovative **robotic limb** inspired by the Swiss army knife that contains many tools such as hammers, drills, and magnetic clamps. The standard omnitool can be utilized for several purposes; if a robot is needed for an even more specific purpose, the omnitool can be taken out altogether and replaced by a new tool. This is economical in that one type of robot can cover several jobs, simply by changing the tool in use. However, repair robots are in their own class, and cannot have these omnitools swapped (for security measures).

5.2 Automation for Maintenance

5.2.1 Required Automated Robots

Name	Function
L-1 Exterior Repair Bot	This robot's main functions including laying the metal lining on the exterior structures. The robot is equipped a mechanical arm with the apparatus for welding, and clamps for carrying. Onboard also are a caulking gun, a cutter, a riveter, and a soldering arm, integrated into the omnitool. Also built into the omnitool is a vacuum hood, designed to fit over the tools, to prevent debris from flying off into space. It creates an airtight seal, pumps gas into the environment, and vacuums up any debris afterward. There are grid systems allow the robot to travel quickly all along the exterior of the settlement without flying into space.
L-2 In-Home Repair Bot	The R-2 is an in-home, miniature, multi-function, user controlled robot. It has the ability to identify a variety of minor technical errors from a large database of present problems. It is also capable of video conferencing with technicians if necessary. It also has access to the same inventory list as the inventory management robots, which, although not capable of measuring weight, allow it to classify objects relatively accurately. 
L-3 Electrical Repair Bot	This robot is designed to fix electrical problems in the settlement. It can interface directly with the station servers to automatically and accurately diagnose and predict trouble spots. It is completely shockproof, and is equipped with an omnitool carrying wire strippers, solder and a soldering gun, pliers, wire cutters, screwdrivers, and a potentiometer. It additionally contains a much higher-capacity battery than the other robots, due to the nature of its work.
G-1 Exterior Finishing Bot	Equipped with an omnitool that has a welder, a mechanical arm with a 360 degree rotational hand, drill, laser cutters, an especially high-resolution camera eye, and the aforementioned equipment hood, this robot generally works together with the R-1 in construction. It is capable of using the same grid systems as the R-1, following after the robot to tidy up any repair jobs and to analyze the surfaces for any imperfections.
G-2 Interior Finishing Bot	The C-2's omnitool contains a welder, a mechanical arm with a 360 degree rotational hand, a rivet driver and a cutter. These robots will be equipped with a vacuum "tentacle" for cleaning up any dust and dirt. They also have an arm attached to storage area, made for identifying rubble and waste and placing in storage pack. Inside the settlement is a rail system designed for carrying robots as quickly as possible to and from problem spots.

Table 5.2.1 Maintenance Automation

5.2.2 Solar Flare Survival

The best form of protection is to try not to become exposed as much as possible. However, spacesuits will have extensive radiation protection built into them. During solar flares, leaving the settlement for any reason will be strongly discouraged.

All exterior systems are guarded by radiation protection. Wireless communications will switch to fiber-optic cables during this time. In addition, maintenance robots specifically designed for repairs during periods of solar flares will have a complete suit-like radiation protective armor around them. In addition to this high-density armor, the robots will be given an especially thick exoskeleton and joints made of ceramics mounted over carbon nanotubes, to create as little exposure to radiation as possible.

5.2.3 Contingency Plans

Problem	Automated Response	Resident Protection
Fire	Sodium Bicarbonate dust will automatically be deployed to deal with the problem. Oxygen will shut off.	Class A: sprinklers will deploy. Class B, C, D and K: Small CO_2 Extinguishers will be used while residents are still nearby and electricity will be shut off to all rooms in affected areas; after evacuation, bicarbonate dust deploys and oxygen is shut off.
Atmosphere	Changes in temperature and in atmosphere should not affect the databases and servers, which will be encased in protective shells.	Alarms trigger, and individual suits for residents in nearby areas are deployed. Appropriate responses will then take into effect based upon the situation.
Hull Damage	Any non-necessary systems in the affected areas will shut down. The shells will clamp onto the surface	Alarms trigger, suits will be deployed for protection, and residents will be evacuated to unaffected sectors.
Data Storage	Back-up servers exist at several points in the station. In addition, all changes in information will either already exist on or currently be streaming to Earth.	User data is kept at several different servers onboard the settlement. These are also sent, encrypted so no one can view them, to the Earth servers.

Table 5.2.2 Contingency Plans

5.2.4 Critical Data Access

Critical data is accessible only after passing various security clearance tests. In addition to passwords, any user trying to obtain high-level access will have to pass several biometric security tests. The two main types of biometric scans will be from coupled Palm-DNA scans, which will scan for fingerprints while sampling dead skin cells off of the subject's tissue, and Facial-Iris-Voice recognition scans, which will identify facial structure and eye patterning as the subject speaks his or her password. These two separate kinds of scans will ensure a very secure way to access critical data.

High level access is allowed only for the Network, Database, and Communication Operation Administrators. This level of access requires all on-duty administrators in the same concentration (2-3) to approve of the changes before they can take effect. Having high-level access also gives the ability to reverse any lower-level changes if deemed necessary.

Medium level access is allowed for System Developers, with approval of a single Administrator or four other system developers. Low-level access is allowed to any advanced user, and advanced users are allowed this permission when the System Developer gives them permission.

All level access is able to be queued for approval. This queue sorts based on urgency and time submitted and has its own server for any data being awaiting approval, so once a user has submitted data he or she is able to forget about it. The queue will also notify the user who attempted to write the file with a message indicating approval or denial of the file access.

5.3 Enhancing Livability through Automation

Computing for Residents on Aresam

For enhanced livability on the settlement, we have created a system which satiates all the needs of individuals on the settlement. With the personal device, the Amicus, as well as a SmartHome system, we have been able to integrate home functions with the personal device. Business PC's and

Research PC's are situated within the settlement and access to these specific computers is based off of the network user hierarchy indicated in 5.0. Entertainment PC's are available in leisure lounges which are strategically placed within the statement as well as within each residence.

5.3.1 Robotics for Assisting Individuals

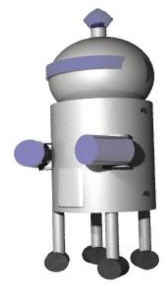
PA Bot	Used in research laboratories, the mechanical arms on this robot allow for handling of hazardous material and provide means of working with substances which scientists otherwise would not be able to. The PA Bot has adapted functions for kitchens, cleaning and others.	Width: 0.5m Length: 0.5 m Height extendable to 1.5 m Up to 4 mechanical arms
SweepClean	A small but handy, intelligent technology powered vacuum cleaner. This little wheeled bot has a 360 degree angle of rotation and is used for in home vacuuming as well as throughout the settlement. It seeks out the presence of any hazardous materials and then sends reports to a maintenance technician. 	Diameter: 0.2m Height: 0.08m
MedAid	This handy robot provides a built in medical aid kid and chatting capabilities with on board doctors. In case of a distress call sent from an Amicus device, the closest MedAid is alerted and this wheel driven robot arrives on scene. Through advances in spectroscopy, it can analyze breath for various imbalances within the body.	Height: 1m Width: 0.5m Length: 0.3m Fitted with first aid kit And communication link with doctors
iGuard	It is equipped with a hazard and navigation camera as well as an emergency siren. It alerts authorities in case of security threats, etc. Moves on a set of wheels. 	Height: 0.5m Width: 0.25m Length: 0.45m

Table 5.3.1 Robotic Assistance

5.3.2 User Interface on Settlement

Amicus Personal Computing Device

It is a handheld all encompassing personal device for the residents of the settlement. Using FOLED technology, the screen is foldable and easily stored. There is a smart stick to which the screen is attached. There is a camera, microphone and projector is located on the smart stick. Touch screen activation of the device is enabled through a fingerprint scan. Security settings are modifiable based on the user's preferences. When using Amicus for monetary transactions or access to sensitive data, face recognition and voice recognition is used through the internal camera and microphones respectively. There is wireless capability on the device. IM capabilities are available through connections between the various Amicus devices. For charging and transfer of data from other physical memory storage devices, there is docking. Wireless charging is available in certain areas of the settlement.

Internet Zero & SmartHome

Internet Zero allows for communication between the various devices that are placed in the home. For example, thermostats are preset, and accordingly, the storage area temperatures are adjusted to suit the nature of the stored items. When medications or food items are running out, the smart storage areas will notify the home occupant by contacting the Amicus. Internet Zero is possible through RFID chips which are implanted into the various appliances and areas within the home. Through this, the various appliances and storage areas communicate with the Amicus. Amicus provides each user with a system which is catered to their personal preferences and settings. It allows each user to connect with others and organize his or her life all through the access to a single device.

On Board Entertainment System

The Entertainment System on board has access to the latest movies, video games as well as music. Video games access comes with the ability to communicate with other users on the settlement as well as the ability to engage in PvP gaming. In the homes, Smart Home comes with HD Audio Surround Sound. Wireless headphones can also be used for optimum hearing pleasure. Music can be shared between the various users on the settlement through playlist connectivity. The streamline design of the entertainment system is built with the touch screen in mind.

Privacy of Personal Data

Access to all of the networking systems on the settlement are all based off the network user hierarchy. To ensure security of data, all money transactions require pins, Amicus or fingerprint verification. Data is fully secure as each residence is composed of a separate data storage device, with no physical access to this data storage device unless one lives in the residence. 'Amicus' requires fingerprint and PIN to verify user upon activation of the device.

5.4 Access to Data Repositories

5.4.1 Human Experiences of Internet on Mars

Search	Copies of Google, etc. are set on Mars servers. New information sent to the database is automatically processed by the search engines for relevance and importance.
News	Updates of public domains (NY Times, LA Times, BBC, CCTV, NDTV, Reuters, NHK) are sent automatically to Mars repository as they happen (about 30 minute delay)
Lifestyle	Updates of public domains (Facebook, Blogger, etc.) are sent automatically to Mars repository (about 30 minute delay to relay to Mars or back to Earth)
E-mail	On the settlement is the MarsMail service. This is required for all users and all updates of the direct settlement are sent to this. MarsMail synchronizes with Earth accounts.
Chat/Video Conference	Only feasible between Mars Residents, due to the lag.

Table 5.4.1 Data Access

5.4.2 Operation of Data Transfer System

Data is sent on Earth from various websites to a site on earth, where it is compressed and transmission is prepared. The data is then routed through multiple laser systems to receivers on Mars, which writes this information onto various servers. Information is decrypted and the server's contents are updated, thus making the Earth information accessible to any users near Mars. Mars servers send information back to Earth as soon as it is available in a similar, but reversed, fashion. Extremely important, time-sensitive information is sent from Earth to Mars or vice-versa through a dedicated line to prevent data backup. This dedicated, secondary two-way data telescope exists solely for critical information, in case important information is not received properly or primary telescope is still processing old information.

We will be creating several repositories of data on Mars that will hold Internet information; the lag will be at most (when Mars and Earth are farthest apart) approximately half an hour. The servers on Mars will hold all information, and receive updated information from Earth- in between the updates, information will be outdated, but any critical/permanent information would still be useful, since the lag period is almost completely negligible. One exception is online gaming; online games must have their own dedicated servers on Mars, because there is no feasible way to replicate split-second interactivity between Earth and Mars. For Internet users, have browsers where a toolbar indicates where information originates from.

If the data has been created on Mars, lag time should be similar to the lag in accessing an Earth-based page from Earth. If the data was created in other places, most likely earth, the toolbar will display data indicating time of the last update, and will alert the user if any updates have been received while the reader was looking at the page. The browser also can be used to request updates of materials to add to a queue, and will alert the user when the updated material will arrive.

In essence our plan establishes Mars's own servers which will have its own set of information. It can accept information from other places such as the Earth or lunar settlements, but will have a half-hour time lag. By having their own servers, most of the Internet on Mars will be instantly accessible. Information from Earth will be slightly behind, but all local data and settlement updates will be fresh.

5.5 Prefabricated Base Automation

5.5.1 Assembly of Prefabricated Base

The basic plan of assembly includes opening a "box" which includes all of the materials and pieces making up the structure of the dome and base. The pieces will be assembled into an elongated dome module. The automations necessary to construct this dome include the use of three major robots, including the THsu Robot, C-2 Exterior Finishing Bot, and G1 Exterior Finishing Bot. The base is initially dropped as a single dome and a middle section cut in half. Two solar panels are already attached to the exterior of the base and a third also arrives. Sheets placed midway between the two sections of the middle to join them. After being put in place, the sheets will be sealed externally and caulked internally. The half domes are then attached to the ends of this new middle section. These external seals lock into place but can be easily removed by triggering the releases for quick disassembly. There is no welding of the base; everything has been designed and prefabricated to latch perfectly into place and create airtight seals.

5.5.2 Laboratory Equipment and Automation

One of the major functions of the prefabricated base is the conducting of research with materials from the Martian surface. We will include a computing set up for the entirety of the prefabricated base which includes various research PC's. There will be high speed videoconferencing for experiments to be conducted between the surface base and Aresam facilities for cooperation between the scientists. The base is also equipped with special sealed containers in which materials from the Martian surface will be placed. When astronauts enter the base from the exterior, through a minor airlock chamber, they will be able to place their samples into one of these specialized containers. All of these specialized containers essentially serve as glove boxes and are placed on a cart, which can be rolled to the lab area.

5.5.3 Internal Systems Control

There is a conditions-monitoring system placed within the Mars settlement. Due to the settlement's complete exposure to the Martian surface, it is imperative that all operations on the prefabricated base have the necessary oversight and conditions are maintained. Therefore sensory systems monitoring pressure, temperature, acoustics, the integrity of the base, and security of the systems are implemented throughout the base. As pictured above, the command center of the base includes an LCD screen displaying the status of all operations within the base.

Figure 5.5.1 Base Control Center

5.5.4 Mining Refinery

A major function of the prefabricated base is to facilitate Martian surface mining. The mining robots deployed with the prefabricated case can analyze the Martial soil using mass spectroscopy. They also can drill and package the materials into boxes. These boxes are then transported back to Aresam. This three step system of discovery, drill and delivery will allow for smooth mining operations. Refer to Section 3 for further information on mining.

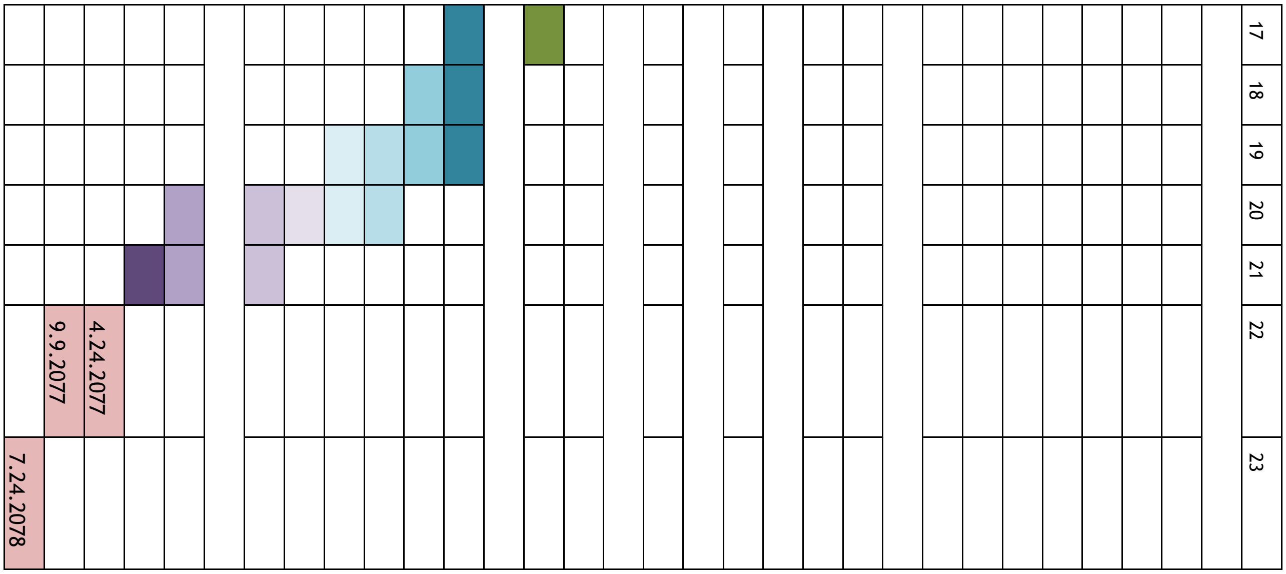
6.0

schedule + cost

SECTION 6: SCHEDULE + COST

6.1 Schedule

Years after 7 May 2055	Workers	Approx. Cost (USD)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Phase 1		40,349,688,750																
Research & development	200																	
Approval by Foundation Society	N/A			Dec. 2056														
Robot & subsystem development	250																	
Central Command system set up	150																	
Communications systems set up	50																	
Hawking satellite set up	80																	
Central Axis constructed	200																	
Phase 2		13,449,896,250																
Pascal port facility constructed	200																	
Ports commence operation	50																	
Phase 3		26,899,979,250																
Graff sphere constructed	250																	
Phase 4		13,449,896,250																
Spokes for tori are assembled	80																	
Phase 5		26,899,979,250																
Watson and *Crick* constructed	150																	
Watson & *Crick* operations begin	50																	
Phase 6		40,349,688,750																
Gauss constructed	150																	
Interior finishing in *Gauss*	Robotic																	
Interior finishing in *Watson*	Robotic																	
Interior finishing in *Crick*	Robotic																	
Establishment of atmosphere	N/A																	
Transportation set up	80																	
Phase 7		26,899,979,250																
Debugging and final system tests	50																	
Commencement of rotation	N/A																	
Foundation Society moves in	N/A																	
All other colonists welcomed	N/A																	
Full population established	N/A																	



6.2 Costs

*See above schedule for estimated employees and cost per phase of construction.

6.2.1 Technology	Cost	Quantity	Total Cost	Annual Upkeep
PCs (normal)	$800	5,000	$4,000,000	$200,000
Servers	$20,000	30	$600,000	$30,000
Storage (Tech)	$45,000	10	$450,000	$13,500
Business Computers	$2,000	2,500	$5,000,000	$250,000
Computer Management PC's	$3,000	50	$150,000	$7,500
Network (components)	$1,750,000	1	$1,750,000	$87,500
Science Research PC's	$2,000	1,500	$3,000,000	$150,000
THsu Robot (Construction Robot)	$350,000	3,000	$1,050,000,000	$84,000,000
C-1 Interior Finishing Robot	$400,000	3,000	$1,200,000,000	$96,000,000
C-2 Exterior Finishing Robot	$400,000	3,000	$1,200,000,000	$96,000,000
C-3 Exterior Assembly Robot	$350,000	3,000	$1,050,000,000	$84,000,000
R-1 Residential Construction Robot	$350,000	3,000	$1,050,000,000	$84,000,000
R-2 Residential Finishing Robot	$400,000	3,000	$1,200,000,000	$96,000,000
M-1 Medical First Aid Robot	$15,000	2,000	$30,000,000	$3,000,000
S-1 Safety Robot	$60,000	5,000	$300,000,000	$24,000,000
I-M Robot	$40,000	3,000	$120,000,000	$9,600,000
PA Robot (Assistant Robot)	$40,000	12,500	$500,000,000	$50,000,000
SweepClean (Cleaning Robot)	$450	12,500	$5,625,000	$281,250
MedAid (Medical Aid Robot)	$15,000	2,000	$30,000,000	$2,100,000
iGuard (Security Robot)	$10,000	5,000	$50,000,000	$6,000,000
Omnitool	$2,000	150,000	$300,000,000	$21,000,000
Amicus Personal Computing Device	$1,500	25,000	$37,500,000	$2,250,000
Card Readers	$500	175,000	$87,500,000	$4,375,000
Central Computer	$16,500,000	1	$16,500,000	$2,475,000
Supercomputers	$2,500,000	20	$50,000,000	$6,000,000
Repair Facility	$26,700,000	5	$133,500,000	$9,345,000
Development			$320,000,000	
TOTAL COST			$8,745,575,000	$681,164,750

6.2.2 Transportation	Cost	Quanitity	Total Cost	Annual Upkeep
Freight Subway	$75,000,000	2	$150,000,000	$15,000,000
Magnetic Railways	$3,000,000	10	$30,000,000	$3,600,000
TOTAL COST			$180,000,000	$18,600,000

6.2.3 Annual Wages	Wages	Number Employed	Total Cost
Technician / Engineer	$165,000	1,300	$214,500,000
Worker (Averaged)	$85,000	16,100	$1,368,500,000
Government Official	$120,000	650	$78,000,000
Researcher	$120,000	1,500	$180,000,000
Teacher	$35,000	30	$1,050,000
Security Personnel	$57,500	200	$11,500,000
Planner*	$200,000	60	$12,000,000
TOTAL Wages			$1,853,550,000

*Planners are paid a lump sum of $200,000 each during construction.

6.2.4 Communication	Cost	Quantity	Total Cost	Annual Upkeep
Fiber optic cables	$15	375,000	$5,625,000	$112,500
Lasers	$6,000	15	$90,000	$4,500
Intercom	$5,000	1	$5,000	$350
Wireless LAN	$550	250	$137,500	$6,875
Satellites	$1,050,000	5	$5,250,000	$682,500
Development			$1,500,000	
TOTAL COST			$12,607,500	$806,725

6.2.5 Materials	Cost	Quantity	Total Cost	Annual Upkeep
Nitrogen (m^3)	$60	250,000,000	$15,000,000,000	$0
Oxygen (m^3)	$0.30	140,000,000	$42,000,000	$0
Carbon Dioxide (m^3)	$0.01	150,000	$1,500	$0
Water (m^3)	$1	3,000,000	$3,000,000	$42,900
Demron Cloth (m^2)	$300	25,000,000	$7,500,000,000	$300,000,000
Silica Aerogel (m^2)	$6	1,250,000,000	$7,500,000,000	$300,000,000
6061-T6 Aluminum Alloy (kg)	$12.70	1,000,000,000	$12,700,000,000	$508,000,000
Polyethylene Foam (m^3)	$324	75,000,000	$24,300,000,000	$972,000,000
Polyethylene (m^2)	$0.64	25,000,000	$16,000,000	$640,000
Solar panels (m^2)	$650	3,000,000	$1,950,000,000	$1,000
Ring Motor	$100,000	2	$200,000	$1,000
Steel Cargo Boxes	$125	350,000	$43,750,000	$2,500,000
TOTAL COST			$69,054,951,500	$1,108,042,900

6.2.6 Landscaping	Cost	Quantity	Total Cost	Annual Upkeep
Trees	$10	10,000	$100,000	$2,000
Grass (m^2)	$8	250,000	$2,000,000	$2,000
TOTAL COST			$2,100,000	$4,000

6.2.7 Housing	Cost	Quantity	Total Cost	Annual Upkeep
Single Residences	$200,000	6,000	$1,200,000,000	$840,000,000
Double Residences	$275,000	4,000	$1,100,000,000	$781,647,058

Family Residences	$350,000	1,000	$350,000,000	$263,666,667
Schools	$800,000	4	$3,200,000	$1,877,333
Parks	$750,000	4	$3,000,000	$1,788,000
Hospitals	$11,000,000	4	$44,000,000	$27,500,000
District/Community Centers	$1,350,000	4	$5,400,000	$2,457,000
Offices	$2,540,000	8	$20,320,000	$5,410,550
Museum	$1,850,000	1	$1,850,000	$1,084,035
Library	$2,150,000	1	$2,150,000	$928,000
Hotel	$19,906,500	4	$79,626,000	$15,925,200
Development			$100,000,000	
TOTAL COST			$2,909,546,000	$1,942,283,843

6.2.8 Totals

Construction Costs	Total Cost
Technology	$7,333,700,000
Transportation	$180,000,000
Wages (Planners only)	$12,000,000
Communication	$12,607,500
Material	$69,054,951,500
Landscape	$2,200,000
Housing	2909546000
Transportation Costs	$108,793,542,496
TOTAL	$188,298,547,496

Annual Costs	Total Cost
Technology	$681,164,750
Transportation	$18,600,000
Wages	$1,853,550,000
Communication	$806,725
Material	$1,108,042,900
Landscape	$4,000
Housing	$1,942,283,843
TOTAL	$5,604,452,218

Annual Revenue	Total Income
Tourism	$1,188,535,186
Recreation	$823,504,990
Hotels	$860,010,988
Net Trade Revenue	$8,041,477,651
Manufacturing	$10,201,290,151
Private Contracting & Advertising	$193,214,573
TOTAL	$21,308,033,539

Amount of Time to Break Even

Calculus

188298547496+5604452218X = 21308033539X

188298547496 = 15703581321X

X = 11.991

12 years to break even

1.0

business development

SECTION 7: BUSINESS DEVELOPMENT

Aresam will be host to a variety of flourishing business operations, establishing it as the first major trading center of what will surely be many more to follow. The flexible design of business facilities allows for expansion into various industries and accommodation of future growth.

7.1 Transportation Node and Port

7.1.1 Docking and Warehousing

Intragalactic freight ships will dock at one of the five ports located on the top level of a specialized, non-rotating column connected to the central axis. This column is called Pascal. The entire area will be subject to microgravity due to the absence of a centripetal force. Meanwhile, shuttle ships between Mars and Aresam may dock at any of the five ports located in the lower level of Pascal.

Pascal is integral to transportation and trade between Mars, Aresam, Earth and other settlements. It has a radius of 215m. An area with a 50m radius centered on the central axis will be free of ships to maintain the safety of the central axis. This leaves a 165m width for loading and unloading purposes. Out of this 165m width, 15m along the outside is used for the radiation shielding material, leaving us with 150m width. Therefore, there will be enough space in each dock to safely and comfortably accommodate sixteen freight ships, assuming each conventional freight ship is at 30m long, 10m wide, and 10m tall. As these dimensions are extremely large, it is possible to accommodate any ship – regardless of shape or design – smaller than these dimensions; therefore, our estimate of sixteen ships is quite conservative, and our ports will be quite flexible. The standard freight ships are extremely spacious to accommodate large amounts of transport between Mars and Aresam and to accommodate materials needed for the establishment of industrial enterprises at any location desired, especially on nearby asteroids and on the Mars surface itself. For more information on the cargo management system, please refer to 7.1.2. Technical and medical examinations will be performed in a secure and sterile area, as indicated in Section 7.1.3.

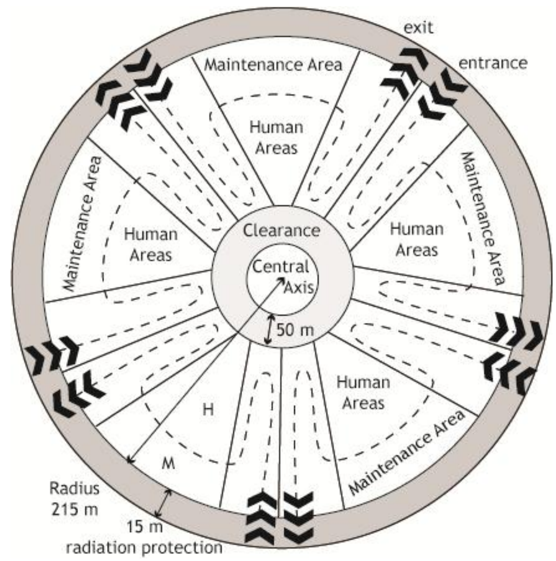


Figure 7.1.1 Layout of one level of Pascal

The loading and unloading of ships is completely automated. Ships enter the port from the left entryway and are guided to an unloading zone by Aresam's central computer system. Aresam overrides the ship's controls to reduce traffic congestion, as the computer itself will then direct traffic through LaserGuide, an innovative technology. First, the pilot will voluntarily surrender control of his ship by deactivating its navigational system. Second, a laser receptor on the ship will receive instructions from a mounted laser beam, which sends information by encoding it into the beam. Next, the ship will transmit its vital data, such as model number, time traveled, and other statistics, through a laser aimed at a sensor located below the mounted laser. The vital data gathered by LaserGuide is then used at RepairCommand, as indicated in Section 7.1.3. LaserGuide facilitates communication between the ship and the settlement's main computer. Upon reaching its proper unloading position, the presence of the ship disrupts a laser circuit and activates a request for unloading. Please see section 7.1.2 for more information on the inventory management system.

For transportation of living beings, a separate, underground pod-system will transport these organisms from the ports through the central axis to their destinations.

7.1.2 Cargo Handling and Standard Port Inventory Management System

Element	Description
Computer	• Serves as the central computer for the storage grid • Coordinates the locations of the storage boxes and reads the barcodes for each box • Arranges requests for storage and for withdrawal • Consists of the complete inventory that is stored in the storage grid
Cargo Boxes	• Made from steel and holds 125m^3 of materials at maximum • Structured as a cube with side lengths of 5m • Coated with Velcro to fasten to loading ships, ensuring that boxes do not float away • Contains barcode on side that codes for what type and how much of a material is in box • Managed by overhead clamps
Overhead Clamps	• Thirty-two overhead clamps in each port grab boxes and transport them between ships • Large enough to grab onto the boxes • Connected to an intricate railway on "ceilings" of ports • Each reads barcodes on cargo boxes, transmits information to central computer, and "knows" where to store or eject materials
Conveyor Belt	• 5.5 m wide with numerous large carts to secure cargo boxes • Once overhead clamp places box into cart on conveyor belt, interrupts laser-based sensor system and activates metal mesh • Transports boxes to the torus through the central axis and vice versa

Table 7.1.1 Cargo and Inventory Management

7.1.3 Medical and Quarantine Services

Ships will enter the air-locked, unpressurized Robotic and Electronics Cleaning Facility, also known as REC-F. REC-F will have magnetic filters stationed near each door, promoting the capture of particles that may detach from the ships. Each filter is a large electromagnet housed in a container. Cleaning robots, equipped with a lint-roller-like apparatus, will remove foreign particles, such as dust contamination, from the exterior of the ship. After the lint-roller robots clean each part, another group of robots will remove the remaining particles through the principle of electrostatic charge, and then cover the ship with biodegradable plastic film to provide a temporary and replaceable shield against the elements of space. The film will be stored in large rolls and can easily be dispensed by that group of robots. Along the walls of REC-F will be recharging booths especially for these robots.

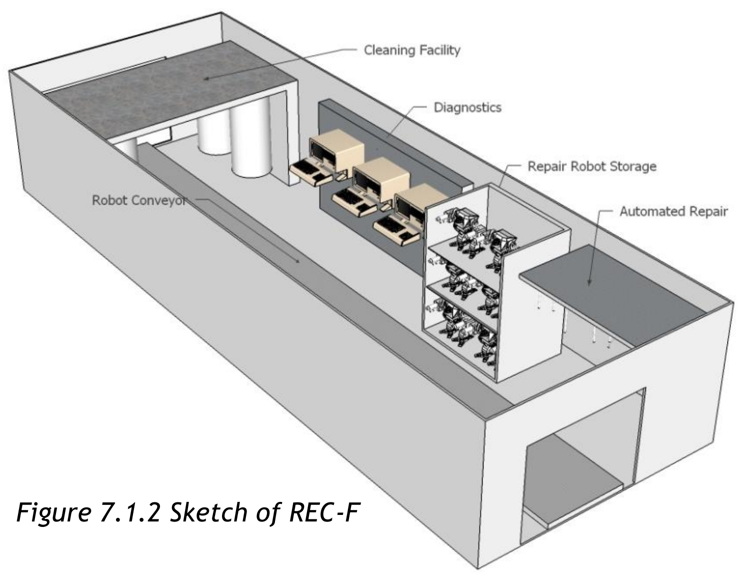


Figure 7.1.2 Sketch of REC-F

Once cleaning is completed, the ship will proceed through an air-locked door and enter the unloading region. After the ship's cargo is unloaded and refueling is completed, the ship will then proceed to a compartmentalized central area of the port. The central area of each port is dedicated to conducting health examinations on passengers and crew members, immigration processes, repairs on incoming ships, and check-ups on the ship robots.

A facility at the center of each port will be situated between the incoming and outgoing traffic lanes. This facility is known as Omnihealth. The bases of Omnihealth will be 200 meters along the edge of the port and 45 meters on the side near the fueling and storage area. The height of the trapezoid will be around 150 meters, leaving a 25 meter corridor-like border on the sides of the trapezoid for ship and cargo movement. Completely quarantined from the rest of the dock, Omnihealth ensures the safety of the entire settlement by decreasing possible transmission of foreign particles from passengers and livestock. Omnihealth is closed off from the rest of the port to maintain the integrity of the port itself.

The first compartment of Omnihealth serves as a pressurized quarantine region for the incoming crew and passengers. Seven doctors and three veterinarians per facility will be available at all times to run regular check-ups on the incoming crew and livestock. Helper robots, programmed to carry out basic tasks such as measurements, and medical supplies are available. Should any disease or anomaly be detected, the check-up area will immediately isolate itself through the use of sealing doors.

After livestock, passengers, and crew members are medically examined, they will proceed to a sterile, pressurized immigration processing area, involving sign-in, registration, and obtaining legal documents such as the ID card. After the appropriate immigration processes are completed, passengers will enter a sealed-off region, where infrared light sterilizes the environment. They will enter a capacious elevator that will transport them to an underground level, and a pod-system in each facility will transport both humans and livestock through the central axis to their destination. Crew members of a ship may either decide to travel to the residential torus with the rest of the passengers to find a pit-stop-type area, where food and living quarters are available to them until departure, or return to the check-up their ship in the repair facility. Back at the residential torus, crew members will enjoy entertainment that is parallel to that enjoyed by permanent Aresam residents and will be located near those temporary living quarters. These temporary living quarters can house up to 2000 transients.

7.1.4 Machinery and Ship Repair and Maintenance Services

Other than the examination of people and livestock, ships and their robots must also be examined. A large portion of Omnihealth will be dedicated to ship and robot examination and repair. Human technicians, assisted by robots, will check the engines and conduct any other necessary repairs. Ships are then linked to a central computer system and undergo various diagnostic tests, including X-ray screening for damage, check-ups for the ship's own navigational system, and engine tests. Omnihealth has all necessary equipment - such as spare parts, tools, and robots - to perform repairs deemed necessary by the computers. Five engineers are available at all times for required inspection and adjustments. If the crew feels it necessary, however, they may also request other repair services through the computer. Ships that need prolonged examinations and repairs will be moved to a separate repair-intensive area.

A section of Omnihealth is specialized to serve robots. Lint-roller robots will clean off all debris from a malfunctioning robot; then, an X-ray machine will examine the damaged robot to pinpoint weakened areas. The robot will then be hooked up to the central computer, where diagnostic tests will be run to determine the issue. Repair robots within the compartment will replace damaged parts, reinstall software for the damaged robot, and run a final diagnostic test to ensure the robot can properly perform all of its functions.

Waste processing will also be highly systematized in the central facility of each port. After waste is deposited into steel boxes designated by barcodes for only waste, waste collection robots in each repair facility will lift the boxes and set the Velcro-surrounded steel boxes onto the cargo-designated conveyor belt. These "waste boxes" on the conveyor belt will then be transported to the waste processing center located in the central axis.

7.1.5 Provisioning and Maintenance Base for Visiting Spacecraft

Element	Description
Fuel types available	• Hydrazine • Nitrogen tetroxide • Helium-3 • Deuterium • Other fuels available upon 6-month advance request
Fuel storage	• Large double-walled tanks • Tanks under high pressure and low temperatures • Each tank will hold only one type of fuel • Color-coded and barcoded for what type of fuel each tank holds

Security	• Fuels stored in stable environment in ports • Only high access level robots have access to deposit or withdraw fuels • Security cameras strategically placed throughout the storage • Temperature monitors monitor stability of environment and detect living beings • When living being is detected, storage area seals off and quarantines suspect • Guards will surround the storage area and capture the suspect

Table 7.1.2 Spacecraft Provisioning

7.1.6 Implemented Technologies for Dust Prevention and Treatment

Element	Description
Airlocks	• Prevent air from flowing out of settlement; prevent particulate matter from flowing in
Magnetic air filters	• Mounted next to and above every door • Will draw in particulate matter that contains metals or are charged • Weak enough to prevent interference with machinery, yet strong enough to efficiently perform its task
Scrub robots	• Robots with lint rollers and brushes • Located near all entrances and exits • Ensure that all machinery that passes by will be cleaned of all dust
Secondary "fluff" screen	• Located after each airlock • When robots enter, they will pass through large screens of carpet-like material • Robots will rub against the fluff screen and be wiped clean of the great majority of dust • Works on the same principle as carwashing machinery, except without water

Table 7.1.3 Dust Prevention

7.2 Manufacturing Center

Aresam will host a manufacturing center; this will help reduce costs and increase productivity of the settlement. This manufacturing center will have extended capabilities: it will be able to produce all sorts of vehicles, tools, machinery, robots, and the prefabricated bases that Mars will demand. This is possible due to the flexibility of the manufacturing center, as it is based on a series of conveyor belts and robotic arms. Products and their instructions will be pre-programmed into the computers that control the manufacturing center.

The resources that Aresam will use originate mostly from Phobos, Deimos, and Mars. In fact, due to the ingenuity of Aresam's design, 90% of the settlement and its exports will be derived from local materials. To illustrate this point, we offer an example: Phobos and Deimos are especially rich in silicates, magnetite, iron, and magnesium. Therefore, it is possible to derive iron, magnesium, steel, oxygen, water, silicon, and various other materials merely from local sources. These metals and other materials make it possible to construct durable vehicles and robots, as well as a great majority of Aresam's other demands such as the prefabricated bases. For more exotic materials that cannot be locally obtained, such as carbon nanotubes or rare metals for industrial and research uses, Aresam will trade with other settlements in the solar system.

7.2.1. Description of Manufacturing Processes in Aresam

Aresam, with its unique structure, will be able to accommodate the essential processes of manufacturing. We have identified the following processes as integral to manufacturing: mining and ore retrieval, refining, waste disposal, transport, quality control and server location, packaging, and assembly. Mining and ore retrieval will be hosted in a non-pressurized, non-rotating area. Refining will also take place in a non-pressurized, non-rotating area. A pressurized and rotating area will contain waste disposal. Transportation will take place in non-pressurized, rotating areas. Quality control takes place in pressurized, rotating areas. Packaging is best allocated in a rotating and non-pressurized area, whereas assembly belongs in a non-pressurized and non-rotating area. For the rationale behind each of these assignments, please refer to the Appendix – Trade Studies for more information.

7.2.2 Production Line Sketch

This simple diagram illustrates a few key points about production lines on Aresam. Goods will be transported primarily through means of a conveyor belt. In this assembly scene, the goods will be unpackaged and assembled in the next step, illustrated by the device through which the belt runs. The device monitors the assembly of the product and accepts remote human instructions. After the product is assembled, it is then transported to the next section in the production line: quality control. By compacting processes and by ensuring monitoring and control at each step, Aresam is truly unique and efficient.

Figure 7.2.1 A representative scene of a production line

7.2.3. Transportation of Vehicles, Robots, Food, and Commodities to Mars

Aresam will continuously send materials to the surface of Mars by packaging all materials into drop-off crates. These crates are made of metal, similar to storage crates on the settlement itself, as metal is abundant on Mars. The materials within are packaged with biodegradable plastic. The crates will be ejected from Aresam and will be captured by the gravitational field of Mars; they will then land on Mars at carefully calculated drop-off points, similar to parachuting. We have decided to use parachutes on these crates instead of thrusters for economy of fuel and for safety of the Mars population. Upon impact, a reusable device on the crate will activate and emit radio signals for the Mars population to track and gather them. For food and other commodities, the crate will be packed with only one type: for example, there will be clothing crates, food crates, and other such specially labeled crates. When sending machinery, the crates will contain two things: the prefabricated, disassembled product and a few small assembly robots that will help humans assemble the robot or vehicle upon demand. This way, Aresam will be able to efficiently send crates, without waste.

7.3 Research Capabilities

7.3.1 Laboratories

Aresam will provide for scientists in space. A scientist who is selected to arrive at Aresam will submit a proposal for a laboratory to his own specifications; this allows the scientist to customize his lab as he wishes, so that he may perform research. These customized laboratories will be located in the central axis if they do not require gravity. If they do, they will be placed in the torus. After a scientist submits his proposal, a panel will review this proposal and determine the estimated cost of such a project; the scientist will then need to agree to pay for the laboratory. After this agreement, the laboratory will be built by subcontractors, the scientist will be charged, and the scientist will have his own facilities, made exactly to his own specifications.

7.3.2 Computing facilities

Supercomputers will be housed in the central axis, due to both microgravity and low temperatures, both of which are essential to increasing processor efficiency and speed. Information will be sent both through a wireless connection and fiber-optic cables, and the information will be encrypted. The cables have a transfer capacity of 5 terabytes per second, and the wireless connection has a transfer capacity of 500 gigabytes per second. Most ordinary information will be sent through the wireless connection; the cables will be utilized for secure information, such as confidential plans and supercomputer projects.

7.3.3 Selection Process of Commercially Viable Goods

To maximize profitability, Aresam naturally will seek new materials available on Mars, Phobos, and Deimos. These new materials will undergo a rigorous evaluation process, to determine whether they are worth exploiting. First, the revenue potential of each commodity will be calculated. This can be determined through statistical analyses and scientific experimentation on its properties; after its properties have been determined, it will then be considered as a material for creating new goods. For instance, should a new substance be malleable, strong, and heat-resistant, it would be considered as a possible new structural material. Then, estimates of its potential value will be made, based upon its properties. When this is done, the values of its potentials will be summed up. After, costs analyses must be done on the commodity. One must keep in mind transportation costs; conservative estimates of cost for transportation generally are around $1000 per pound, or $2200 per kilogram. Then, processing and manufacturing costs must be considered. After all, should a valuable ore require expensive and intensive processing, and its potential value is below those costs, it cannot be considered profitable. Storage costs must also be considered; volatile gases and dangerous substances require special containers, and these must be considered in the selection process as well.

When a resource has undergone all of these steps – evaluation of value based on potential uses, and evaluation of costs based on transport, processing, manufacturing, and storage – it will then be considered a commercially viable resource if its value exceeds its cost. It may then be exploited for further gains. However, even if a resource does not manage to have its value surpass its cost, it may still be under consideration; as time passes, and as technology advances further, it is possible that the resource's value will rise or its costs will fall. At that point, it may be exploited.

7.3.4 Capabilities to Produce New Commercially Viable Products

Aresam will provide 50m by 50m plots of land to companies for industrial uses. Multiple plots can be bought together to be combined into a larger plot. On each of these plots, there will be a standard control center with the latest surveillance, control, and safety technology available for humans to control robots. Aresam will also lease machinery and will sell custom-ordered machinery for companies; Aresam will further assist in the construction of any factories or buildings that companies may need. In this way, by facilitating companies to move in and start production, Aresam provides capabilities to produce new commercially viable products. Should no company be currently available to produce a certain product that has been deemed commercially viable, Aresam itself will create and manage a new corporation, which will then be in charge of creating that product and making profits.

7.3.5 Laboratory Configurations

All laboratories, while built to custom specifications made by researchers, will follow a basic laboratory design to promote safety and convenience. In case of emergency, researchers will have access to a button that will set off multiple processes. First, a lab-wide alarm will set off, and researchers will be directed to the first room of the LifeDefense structure. They will have 10 minutes to safely stop whatever they are doing and evacuate. The entire lab will be sealed off to all humans; only high-level security and maintenance robots may enter, after providing authorization codes.

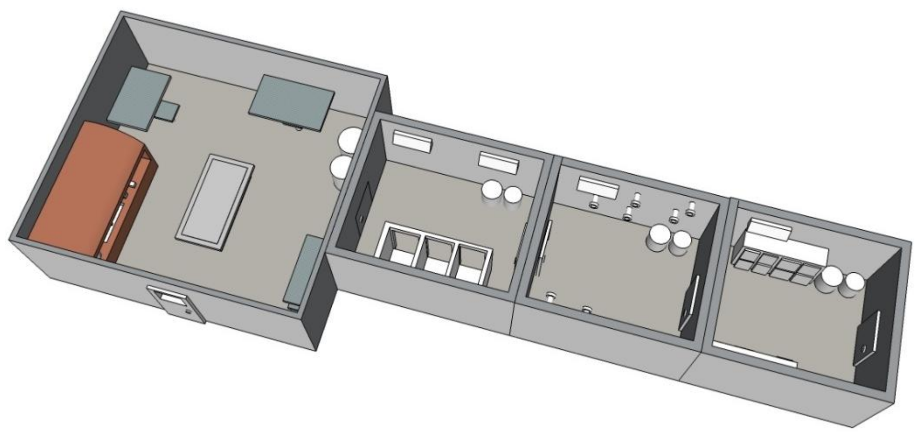


Figure 7.3.1 The basic outline of a laboratory and its LifeDefense

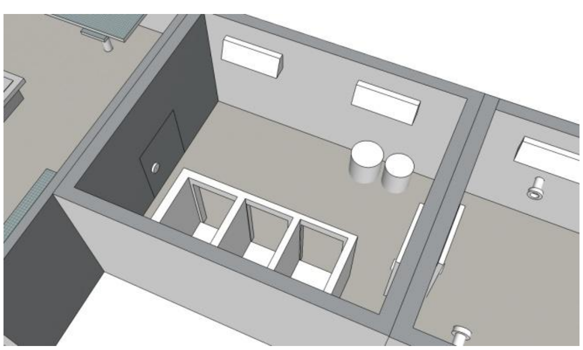


Figure 7.3.2 The first room of LifeDefense

In this first room, researchers will strip off their clothes to prevent further contamination, and will dispose of them in biohazard containers. Airlocked doors and a local ventilation and air circulation system - created by the release of air from isolated air tanks will prevent spread of airborne contaminants. Infrared lamps located strategically in the room will kill off bacteria and other foreign life forms while not affecting the researchers' health. This room will remain available for approximately half an hour; then all researchers must evacuate, as the air will run out. Researchers will then go to the second room of the LifeDefense system. An alarm will sound when there are 10 minutes left, and another will sound when there are 5 minutes left.

The second room will have shower heads that dispense a mist containing antibiotics and antibacterial chemicals. The unclothed researchers will be required to stay in this room for at least 15 minutes, to fully decontaminant themselves. There will be infrared lamps here as well. After an hour, this room will lose its air as well. An alarm will sound when there are 10 minutes left, and another will sound when there are 5 minutes left. Researchers will then all go to the exit. This room is airlocked as well.

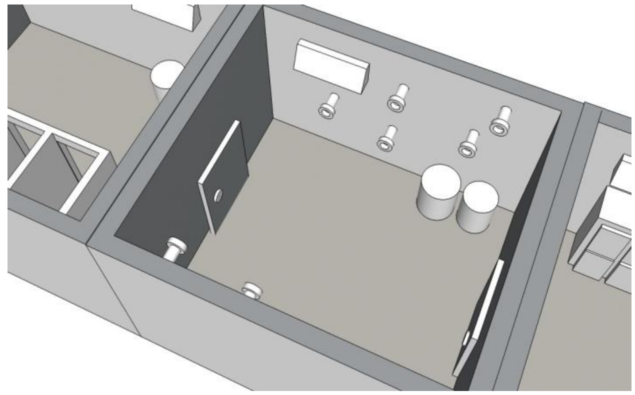


Figure 7.3.3 The second room of LifeDefense

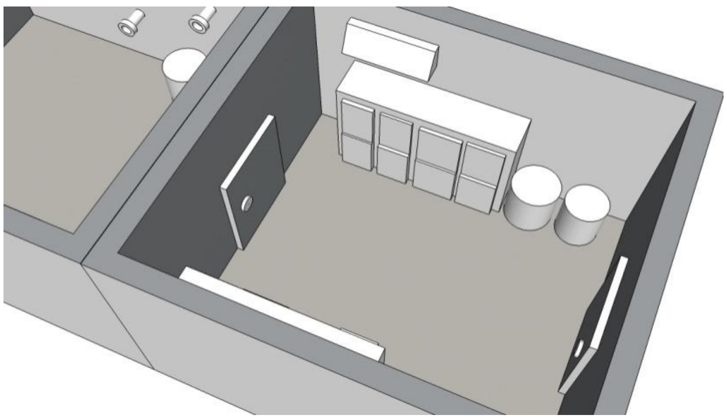


Figure 7.3.4 The final room of LifeDefense

The last component of LifeDefense is the exit room. It contains clothing for evacuated researchers. The doors are airlocked, and the air tank contains enough air for two days for ten people. An infrared lamp here will ensure the safety of the researchers. At the exit interface, the researchers will be able to leave the LifeDefense in an orderly procedure that will maintain the integrity of the settlement and isolate the laboratory. When all researchers have left, the entire laboratory will deactivate, and only robots will be able to access and reactivate it. Reactivation occurs 14 days after the laboratory is deemed safe enough for humans to return.

8.0

appendix

a. detailed assesment
b. references
c. compliance matrix

SECTION 8: APPENDICES

The following appendices describing thought processes and rationale as well as reference works are provided for the perusal of the Foundation Society.

8.1 Detailed Assessment: Trade Studies

The purpose of this section is to evaluate the location of each manufacturing process. We have identified the following processes as integral to manufacturing: mining and ore retrieval, refining, waste disposal, transport, quality control and server location, packaging, and assembly.

8.1.1 Methodology

The following format will apply to our trade study analyses. We will first introduce the relevant process with a short summary. This will be followed by a trade study diagram. The following abbreviations are used for convenience:
PR – pressurized and rotating area
PNR – pressurized and non-rotating area
NPR – non-pressurized and rotating area
NPNR – non-pressurized and non-rotating area

We will evaluate the following five criteria: Safety, Efficiency, Community Impact, Access, and Human Oversight. We will use a scale of 1 to 10 per category, 1 being the worst and 10 being the best. At the end of each diagram, there will be a totaling of scores; the highest-scoring area is the area in which to house the specific process.

8.1.2 Mining and Ore Retrieval

Aresam will extensively mine for resources to accelerate its growth and provide materials for industrial, commercial, and personal purposes. We will mine from various asteroids, Phobos, Deimos, and Mars. Aresam's mining robots are designed to harvest a substantial quantity of ore per trip. Therefore, we seek an area to safely unload these robots. We seek to promote efficiency, reduce the disturbance of the community, maximize access, and provide for human oversight.

	PR	PNR	NPR	NPNR
Safety	4	7	4	8
Efficiency	4	6	6	4
Community Impact	2	5	5	9
Access	7	5	6	4
Human Oversight	6	5	4	4
TOTAL	**23**	**28**	**25**	**29**

Clearly, a non-pressurized non-rotating area is best for ore retrieval. While it is mildly difficult to access, this area has the highest safety rating and the least negative impact on communities. While it is inherently hard to establish human oversight in non-pressurized areas, we will implement surveillance and remote control technologies to alleviate this.

8.1.3 Refining

Aresam's mining robots will partially refine ores upon harvesting its maximum load. In this way, the harvest takes up less space, and less space is required in the settlement for further refining. Rather, the space within Aresam itself will serve for further ore purification for industrial or scientific purposes.

	PR	PNR	NPR	NPNR
Safety	4	7	5	9
Efficiency	3	5	5	8
Community Impact	3	5	5	8

Access	8	6	5	4
Human Oversight	6	5	4	4
TOTAL	**24**	**28**	**24**	**33**

Clearly, a non-pressurized non-rotating area is optimal for refining purposes. While it is mildly difficult to access, this area has the highest safety rating and the least negative impact on communities. While it is inherently hard to establish human oversight in non-pressurized areas, we will implement surveillance and remote control technologies to alleviate this.

8.1.4 Waste Disposal
An important component of manufacturing is dealing with its byproducts. Waste is an especially important topic to us, as we strive to maintain our environmentally friendly and socially responsible attitude.

	PR	**PNR**	**NPR**	**NPNR**
Safety	7	5	4	2
Efficiency	9	4	6	3
Community Impact	4	5	6	7
Access	9	5	5	3
Human Oversight	10	7	5	4
TOTAL	**39**	**26**	**26**	**19**

A pressurized, rotating area serves the purpose of waste disposal the best. Humans can easily access this type of area. As there will be no floating trash due to gravity, efficiency, safety, and oversight greatly improve in rotating areas. Pressurization facilitates human access even more; however, one would need to take care in isolating the air within the facility so as to prevent possibly contamination with the air of the settlement itself.

8.1.5 Transport
After manufacturing, Aresam will need to transport its products throughout the settlement for distribution to its residents and to its ports. Transportation is an integral part of manufacturing; therefore, it is important to establish the areas in which the efficiency of transportation can be maximized.

	PR	**PNR**	**NPR**	**NPNR**
Safety	8	6	8	6
Efficiency	7	5	8	5
Community Impact	5	6	6	7
Access	7	5	6	3
Human Oversight	8	5	7	5
TOTAL	**35**	**27**	**35**	**26**

Oddly enough, both a pressurized rotating area and a non-pressurized rotating work equally well. The other two types do not work will because of lack of access, lack of human oversight, and lack of efficiency; one cannot harness gravity for transportation if one does not have gravity, and non-rotating areas have no gravity. Whatever non-pressurized facilities lose in ease of access, it easily makes up for in terms of reduced maintenance costs. Therefore, though both pressurized and non-pressurized rotating areas work equally well, at Aresam we will use a non-pressurized rotating area to reduce maintenance costs and to promote efficiency.

8.1.6 Quality Control and Server Location
Aresam prides itself in its ability to provide the highest quality goods at the lowest price. One of the key components of Aresam's leadership in the production of goods is its unique quality control system, which takes place at every step of manufacturing. We find it essential to promote quality control, and

hence the server location where humans and computers interface remotely with the manufacturing process.

	PR	PNR	NPR	NPNR
Safety	9	8	4	2
Efficiency	10	7	4	3
Community Impact	4	6	8	9
Access	8	6	3	1
Human Oversight	10	8	3	1
TOTAL	**41**	**35**	**22**	**16**

As humans are involved, a pressurized and rotating area is safest and easiest to access. Humans tend to work better in familiar environments; the presence of both gravity and air greatly enhances the motivation and satisfaction of employees, whereas a non-rotating and non-pressurized area serves to demoralize the workers. In fact, areas with no air are extremely dangerous to humans, especially if they do not follow safety procedures. Therefore, to maximize safety, efficiency, and satisfaction of the workers, we have opted to use a pressurized and rotating area for quality control, even though this will mildly impact the community.

8.1.7 Packaging

Our settlement is not only responsible for manufacturing products; Aresam is also responsible for delivering safe and properly packaged goods. Gravity helps to improve the efficiency of packaging, as less machinery is required to manipulate the goods.

	PR	PNR	NPR	NPNR
Safety	8	8	8	8
Efficiency	5	2	8	4
Community Impact	3	6	6	8
Access	7	5	5	5
Human Oversight	8	7	7	7
TOTAL	**31**	**28**	**34**	**32**

A non-pressurized area with gravity is optimal for packaging. One may take advantage of centripetal force in packaging. A pressurized area is unnecessary here, as few humans will directly work with packaging; rather, the process is remote controlled. Therefore, a rotating and non-pressurized area is best for the packaging process.

8.1.8 Assembly

One of the most important aspects of manufacturing is assembly. Efficient assembly greatly boosts the bottom line, whereas poor assembly is not only undesirable but also potentially dangerous. Gravity wears down machines faster, and air causes machines to run less efficiently. As assembly is entirely automated, one need not worry about the safety of humans, who will oversee the process remotely.

	PR	PNR	NPR	NPNR
Safety	8	8	8	8
Efficiency	3	5	6	9
Community Impact	2	5	5	8
Access	7	5	5	5
Human Oversight	9	8	8	8
TOTAL	**29**	**31**	**32**	**38**

Non-pressurized, non-rotating areas work the best for assembly. Machines must perform repetitious tasks, and both gravity and air serve to provide friction, which wears down parts faster. As no humans are directly involved with assembly, the lack of air and lack of gravity in the area is no cause for alarm.

8.2 Works Cited

Aerogel. 2005. 7 Mar. 2009 <http://aerogel.nmcnetlink.com/aerogel-cost-manufacturability.html>.

"Bio-Suit." Man Vehicle Laboratory. Massachusetts Inst. of Technology. 7 Mar. 2009 <http://mvl.mit.edu/EVA/biosuit/index.html>.

Bond, Peter. Zero G: Life and Survival in Space. London: Cassell, 1999.

Bonsor, Kevin. "How Space Tourism Works." Howstuffworks. 7 Mar. 2009 <http://science.howstuffworks.com/space-tourism.htm>.

Cain, Fraser. "Space Elevator? Build It on the Moon First." Universe Today. 18 Nov. 2004. Universe Today. 7 Mar. 2009 <http://www.universetoday.com/2004/11/18/space-elevator-build-it-on-the-moon-first/>.

CNN. 7 Mar. 2009 <http://www.cnn.com/SPECIALS/space/station/briefing/spacesuit/spacesuit.gif>.

"Fact Sheet." Irvine Ranch Water District. July 2005. 7 Mar. 2009 <http://www.irwd.com/MediaInfo/factsheet.pdf>.

Freudenrich, Craig C. "How Spacesuits Works." Howstuffworks. 7 Mar. 2009 <http://science.howstuffworks.com/space-suit.htm>.

Graem, H. "Space Habitat." Visions2200. 2006. 7 Mar. 2009 <http://www.visions2200.com/SpaceHabitat.html>.

GRC Ion Propulsion. 27 Feb. 2009. NASA Glenn Research Center. 7 Mar. 2009 <http://www.grc.nasa.gov/WWW/ion/>.

Harrison, Albert A. Spacefaring: The Human Dimension. Berkeley: U of California P, 2001.

"How Do Solar Panels Work?" The Great Lakes Renewable Energy Association. 2006. 7 Mar. 2009 <http://www.glrea.org/articles/howDoSolarPanelsWork.html>.

"How Hydropower Works." Wisconsin Valley Improvement Company. 27 Apr. 2006. 7 Mar. 2009 <http://www.wvic.com/hydro-works.htm>.

"Inconel 625 Technical Data." High Temp Metals. 7 Mar. 2009 <http://www.hightempmetals.com/techdata/hitempInconel625data.php>.

Lad, Kashmira. Who Invented Velcro. 16 Oct. 2008. Buzzle.com. 7 Mar. 2009 <http://www.buzzle.com/articles/who-invented-velcro.html>.

"Lesson Plans & Activities." NASA Advanced Supercomputing Division. 10 July 2002. National Aeronautics and Space Administration. 7 Mar. 2009 <http://www.nas.nasa.gov/About/Education/SpaceSettlement/teacher/lessons>.

Lindsey, Nancy J. "L2 Natural Environment Summary." Vision Mission: The Black Hole Imager. Sept. 1998. Lockheed Martin Technical Operations. 07 Mar. 2009 <http://maxim.gsfc.nasa.gov/documents/Mission_Concept_Work/ISAL_January_2002_SST/SST_ISAL-1/Super_Star_Tracker/L2-natural-environment.pdf>.

"Materials." Web. 10 Jan. 2010. <http://chapters.marssociety.org/winnipeg/materials.html>

McCarthy, John. "Hydrogen." Formal Reasoning Group. 1 June 2007. Stanford U. 7 Mar. 2009 <http://www-formal.stanford.edu/jmc/progress/hydrogen.html>.

McCarthy, John. "What is Artificial Intelligence?" 12 Nov. 2007. Stanford University. 7 Mar. 2009 <http://www-formal.stanford.edu/jmc/whatisai/>.

McMaster, Joe. "An Elevator to Space?" NOVA Science NOW. Jan. 2007. PBS.org. 7 Mar. 2009 <http://www.pbs.org/wgbh/nova/sciencenow/dispatches/070104.html>.

Michon, Gerard P. "Circumference/Perimeter of an Ellipse: Formula(s) - Numericana." PERSONAL WEB PAGES - home.att.net. 25 Dec. 2008. 07 Mar. 2009 <http://home.att.net/~numericana/answer/ellipse.htm>.

Miller, J., L. A. Taylor, M. DiGiuseppe, L. H. Heilbronn, G. Sanders, and C. J. Zeitlin. "Radiation Shielding Properties of Lunar Regolith and Regolith Simulant." Lunar and Planetary Institute (LPI). 2008. Lunar and Planetary Institute. 01 Mar. 2009 <http://www.lpi.usra.edu/meetings/nlsc2008/pdf/2028.pdf>.

"New Weldable High-Strength Wear-Resistant Steel with a Minimum Tensile Strength of 1050 N/mm^2." *SpringerLink*. Springer New York, 25 Jan. 2005. Web. 26 Feb. 2010. <http://www.springerlink.com/content/k50n6630tn568634/>.

“Normal Vestibular Function in Chicks after Partial Exposure to Microgravity during Development." Journal of Vestibular Research 5 (1995): 289-298. 7 Mar. 2009 <http://www.cs.uic.edu/~kenyon/Papers/Chix/Chix.html>.

O'Neill, Gerard K. The Colonization of Space. 7 Mar. 2009 <http://space.mike-combs.com/TCoS.html>.

Onken, Michael. "Re: how much does titanium cost?" Online posting. 21 Nov. 2003. 7 Mar. 2009 <http://www.madsci.org/posts/archives/2003-11/1069433828.Ot.r.html>.

Pearson, Jerome. "Space Elevator and Other Advanced Concepts." Space Elevators Page of STAR, Inc. 7 Mar. 2009 <http://www.star-tech-inc.com/spaceelevator.html>.

“Propellants." John F. Kennedy Space Center. 28 Aug. 2002. 7 Mar. 2009 <http://www-pao.ksc.nasa.gov/kscpao/nasafact/count2.htm>.

Questions and Answers about Aeroponics. 2003. AgriHouse Corp. 7 Mar. 2009 <http://www.biocontrols.com/aero17.htm>.

Raguard - Transparent Radiation Protection Material. Web. 27 Feb. 2010. <http://raguard.com/>.

"Reference Values for Nutrition Labeling." Recommended Daily Intake. 2009. Netrition.com. 7 Mar. 2009 <http://www.netrition.com/rdi_page.html>.

Sibille, L., S. Sen, P. Curreri, and D. Stefanescu. "Development of Metal Casting Molds by SOL-GEL Technology Using Planetary Resources." Lunar and Planetary Institute (LPI). 2000. Lunar and Planetary Institute. 01 Mar. 2009 <http://www.lpi.usra.edu/meetings/resource2000/pdf/7022.pdf>.

"Silica Aerogels." *Environmental Energy Technologies Division*. Web. 27 Feb. 2010. <http://eetd.lbl.gov/ecs/aerogels/aerogels.htm>.

“Solar Panels." CruzPro Ltd. 7 Mar. 2009 <http://homepages.ihug.co.nz/~bvdb/solar.html>.

Space.com. Imaginova. 7 Mar. 2009 <http://www.space.com>.

Spacecraft Ion Thruster. 2009. NASA. 7 Mar. 2009 <http://dawn.jpl.nasa.gov/mission/ion_prop.asp>.

“Space Settlements: A Design Study." NASA Advanced Supercomputing Division. 10 July 2002. National Aeronautics and Space Administration. 7 Mar. 2009 <http://www.nas.nasa.gov/About/Education/SpaceSettlement/75SummerStudy/Table_of_Contents1.html>.

Steere, Mike. "'Space elevator' would take humans into orbit." 8 Oct. 2008. CNN.com/europe. 7 Mar. 2009 <http://www.cnn.com/2008/WORLD/europe/10/02/space.elevator/index.html>.

Stine, G. Harry. Living in Space. New York: M. Evans and Company, 1997.

Sundararajan, Venkatesan. Aluminum Composites in Aerospace Applications. 7 Mar. 2009 <http://home.att.net/~s-prasad/almmc.htm>.

Team 4. "Space Radiation Protection of the Spacecraft and." College of Engineering. 2002. Perdue University. 07 Mar. 2009 <http://cobweb.ecn.purdue.edu/~tatjanaj/NUCL497_2002/Report-12.pdf>.

"The Future of Robots." Mind & Brain. 1 July 2008. Science Daily - Computer Scientists Program Robots to Play Soccer, Communicate with Bees. 7 Mar. 2009 <http://www.sciencedaily.com/videos/2008/0707-the_future_of_robots.htm>.

The Orion's Arm Universe Project. 7 Mar. 2009 <http://www.orionsarm.com/main.html>.

“United States Data Profile." The World Bank Group. Apr. 2007. 7 Mar. 2009 <http://devdata.worldbank.org/external/CPProfile.asp?SelectedCountry=USA&CCODE=USA&CNAME=United+States&PTYPE=CP>.

“Vaio SZ Series VGN-SZ650N C 2.2GHz Intel Core 2 Duo." PC Connection. 7 Mar. 2009 <http://biz.pcconnection.com/IPA/Shop/Product/Detail.htm?sku=7887783>.

Wade, Mark. "Bio-Suit." Encyclopedia Astronautica. 2007. 7 Mar. 2009 <http://www.astronautix.com/craft/biosuit.htm>.

Westfall, Richard, Willam C. Jenkin, and United Societies In Space, Inc. "Space Stations with Gravity." Galactic Mining Industries, Inc. 7 Mar. 2009 <http://www.space-mining.com/spacestation.html>.

Wikipedia. 7 Mar. 2009 <http://en.wikipedia.org/>.

Williams, David R. "Earth Fact Sheet." National Space Science Data Center. National Aeronautics and Space Administration. 7 Mar. 2009 <http://nssdc.gsfc.nasa.gov/planetary/factsheet/earthfact.html>.

"Xenon Ion Propulsion Center." Boeing Public Relations. 2009. Boeing. 7 Mar. 2009 <http://www.boeing.com/defense-space/space/bss/factsheets/xips/xips.html>.

8.3 Compliance Matrix

Requirement	Subsection	Page
1.0 *Executive Summary*	1.0	1
2.0 *Structural Design*	2.0	2
-Provide residence for 20,000 full-time and up to 2,000 transient residents.		
2.1 *Exterior*		
-Identify large enclosed volumes and major structural components.	2.1.1	2
-Show dimensions of major hull components.	2.1.1	2
-Specify construction materials for major hull components and design features.	2.1.2	3
-Specify where artificial gravity will be supplied.		
-Show interfaces between rotating and non-rotating sections.	2.1.3	4
-Rationalize rotation rate and artificial gravity.	2.1.1, 2.1.3	2, 4
-Specify means for debris/radiation protection.	2.1.3	4
-Show capability to isolate at least two of ten separate volumes.	2.1.2	3
-Identify pressurized/unpressurized volumes.	2.1.5	5
-Identify rotating/non-rotating sections.	2.1.4	4
-Indicate functions of each volume.	2.2	5-7
	2.1.1, 2.2	2, 5-7
2.2 *Interior*		
-Specify allocation of down area.	2.2	5-7
-Show drawings with dimensions of residential, industrial, commercial, agricultural, and other sections. Provide overall map of layout.	2.2	5-7
-Show orientation of down area and vertical clearance in each area.	2.2	5-7
2.3 *Construction*		
-Describe construction process and show at least 6 steps of assembly.	2.3	7, 8
-Specify when and how artificial gravity will be initiated.	2.3	8
-Describe use of materials from Phobos and/or Deimos for construction.	2.3	8
2.4 *Expansion*		
-Show design features enabling expansion during transition phases in Mars operations.	2.4	8, 9
-Provide diagrams of systems enabling future expansions, especially in ports.	2.2.1, 2.4	2, 8, 9
2.5 *Prefabricated Base Structure*		
-Create a design for a prefabricated base built from materials from Phobos and/or Deimos that can be transported in one 4m x 4m x 9m container and erected by two spacesuited persons in 10 or fewer hours.	2.5	9
-Ensure that the base is provisioned to accommodate up to 4 people for 30 days.	2.5	9
3.0 *Operations & Infrastructure*	3.0	10
-Describe facilities necessary for building and operating the community, including business and accommodating vehicles.		
3.1 *Orbit and Materials*		
-Recommend a Mars orbital location (altitude and inclination) for Aresam and provide rationale.	3.1.1	10
-Identify sources of materials/equipment for construction/operations.	3.1.2	10, 11
-Identify means of transport for materials.	3.1.2	10, 11
3.2 *Infrastructure*		
-Identify air composition, pressure, and quantity, and describe climate control.	3.2.1	11
-Describe food production: growing, harvesting, storing, packaging, delivering, selling.	3.2.2	11, 12
-Describe how power will be generated (specify kW), distribution, & allocation.	3.2.3	12
-Describe water management (quantity and storage facilities).	3.2.4	12, 13
-Describe household and industrial solid waste management (recycling, disposal).	3.2.5	13

-Describe internal/external communication devices & central equipment. -Describe internal transport systems (show routes, vehicles, dimensions). -Describe day/night cycle provisions (schedules and mechanisms required). -Define storage facilities in case of interruption in food or commodities for up to ten months.	3.2.6 3.2.7 3.2.8 3.2.9	13 14 14 14
3.3 *Construction Equipment* -Show designs of machines for settlement construction, especially hull and interior buildings and structures. -Describe necessary materials and how machines create the structures.	 3.3 3.3	 15 15
3.4 *Harvesting & Refining* -Describe materials harvesting on Phobos and/or Deimos and refining and processing of materials to provide supplies for Aresam operations.	 3.4	 15, 16
3.5 *Prefabricated Base Operations* -Describe air, food, power, water, waste systems required for base operation.	 3.5.1-5	 16
4.0 *Human Factors* -Have natural sunlight and views of Mars below settlement. -Ensure that facilities enable mobility with a minimum of excess motion.	 4.1.1 4.1.1	 17 17
4.1 *Services & Consumables* -Provide services expected from comfortable modern communities. -Ensure that public areas have long lines of sight. -List major categories of consumables and quantities. -Depict and specify means of distributing consumables (incl. food) to residents. -Provide maps/illustrations of communities with locations of amenities and distance scale. -Identify percentage of land area allocated to roads and paths.	 4.1.1 4.1.1 4.1.2 4.1.2 4.1.1 4.1.1	 17 17 18 18 17 17
4.2 *Residences* -Provide designs of typical homes, clearly showing room sizes. Homes must be between 800 and 2000 square feet. -Identify sources and/or manufacture of furniture items and appliances. -Provide external drawing and interior floor plan of at least 4 home designs, the area (in sq. feet) of each design, and the number of each required.	 4.2.1 4.2.2 4.2.1	 18, 19 19 18, 19
4.3 *Access* -Provide means for safe access to any location in parts of settlement with low-gravity, inside settlement or on exterior surfaces. -Show spacesuit designs with stowage and donning/doffing procedures. -Show airlock designs for entering/exiting unpressurized volumes.	 4.3.1 4.3.2 4.3.3	 19 19-21 21
4.4 *Demographic Shifts* -Show examples of flexible housing and community design for anticipated changes in demographics. -Provide chart or table showing anticipated demographic trends for Aresam.	 4.4 4.4.1, 4.4.2	 21 21, 22
4.5 *Prefabricated Base Interior* -Show interior configuration of the prefabricated base. -Provide drawings of base structure interior floor plan and amenities.	 4.5 4.5	 22 22
5.0 *Automation* -Specify number and types of computers, servers, software, network devices, and robots required for facility, community, & business operations. -Include types and capacities of data storage media, collection, distribution, and user access to computer networks in computer system descriptions. -Show robot designs, clearly indicating dimensions and illustrating how they perform their tasks.	 5.0.1 5.0.2 5.0	 23 23 23-29
5.1 *Construction* -Describe automation for construction (transportation/delivery of materials, assembly, interior finishing). -Provide drawings showing automated construction and assembly devices for interior/exterior applications and show how they operate.	 5.1.1 5.1.2	 24, 25 25

5.2 *Maintenance*		
-Specify systems for maintenance, repair, and safety, including backup systems and contingency plans for failures.	5.2.3	26
-Provide solar flare protection for emergency robots.	5.2.2	25, 26
-Describe means for authorized personnel to access critical data and command computer/robot systems; include security measures to assure that only authorized personnel have access (and for authorized purposes).	5.2.4	26
-Provide chart with anticipated automation requirements and systems or robots to meet each need.	5.2.1	25
5.3 *Livability*		
-Specify automation to enhance livability, productivity, and convenience.	5.3.1	27
-Emphasize automation for routine tasks, and reduce manual labor.	5.3.1	27
-Provide for privacy and control of private systems.	5.3.2	28
-Describe devices for personal delivery of internal and external communications services, entertainment, information, computing, and robot resources.	5.3.2	27, 28
-Provide drawings of robots/computers on settlement, and diagrams of networks and bandwidth requirements for connectivity.	5.3.2	27, 28
5.4 *Data Access*		
-Describe access processes to Earth-based information.	5.4.2	28, 29
-Provide table or images with Internet user experiences on Aresam; include messages to identify delays and methods to create illusion of instant access.	5.4.1	28
5.5 *Prefabricated Base Automation*		
-Provide robotic assistants for deployment of prefabricated base.	5.5.1	29
-Provide automation for materials harvesting, refining, and processing on Phobos and/or Deimos.	5.5.2-4	29
6.0 *Schedule and Cost*		
-Provide a schedule with costs through the construction phases of the schedule.	6.1	30, 31
6.1 *Schedule*		
-Describe tasks from time of contract award (May 7, 2055) until customer assumes responsibility for settlement operations.	6.1	30, 31
-Show dates when Foundation Society members may move into settlement and when entire initial population will be established.	6.1	31
6.2 *Costs*		
-Specify costs associated with design in US dollars without inflation.	6.2	31-33
-Estimate numbers of employees per phase of construction.	6.1	30
-Provide charts/tables with separate costs per phase of construction.	6.1	30
7.0 *Business Development*		
-Design of settlement should be able to add compatible business types easily.	7.0, 7.1.1	34
7.1 *Transportation Node and Port*		
-Must have docking, warehousing, and cargo-handling capability to transfer freight between spacecraft (including large-scale industrial cargo).	7.1.2	35
-Must have terminal facilities to handle passengers to and from Mars surface.	7.1.1	34
-Must provide refueling and provisioning services for visiting ships.	7.1.5	36, 37
-Must have a base and repair depot for Mars surface landing/launch vehicles.	7.1.4	36
-Show how Martian dust will be prevented from entering enclosed areas.	7.1.6	37
-Provide medical and quarantine services for isolation of serious illnesses.	7.1.3	35-36
7.2 *Manufacturing Center*		
-Define products including launch/landing and surface vehicles, tools, machinery, robots, and prefabricated bases.	7.2.0, 7.2.3	37, 38
-Identify sources of materials for vehicle, robot, and base construction.	7.2.0	37
-Describe manufacturing processes to be conducted in pressurized, non-pressurized, rotating, and non-rotating volumes.	7.2.1	37
-Illustrate a representative scene from a production line.	7.2.2	37, 38
-Show how vehicles/robots intended for surface operations will be transported.	7.2.3	38

-Show how food and other commodities will be transported to Mars surface.	7.2.3	38
7.3 *Research Center* -Provide laboratories for assay of and experiments with Martian materials. -Provide capability to quickly begin commercial product production. -Describe cost criteria for selecting commercially viable products. -Enable quarantine if hazardous materials are identified.	 7.3.1, 7.3.2 7.3.4 7.3.3 7.3.5	 38 39 38, 39 39, 40
8.0 *Appendices*	8.0	41-50
8.1 *Detailed Assessment* -Provide details and trade study results of analyses to determine best settlement locations of conducting various heavy manufacturing processes. -Take into account efficiency, gravity, pressure, environmental impact, access, and human oversight.	 8.1 8.1	 41-43 41-43
8.2 *Bibliography*	8.2	44-46
8.3 Compliance Matrix -List each requirement in SOW and page where the requirement is addressed.	8.3	47-50