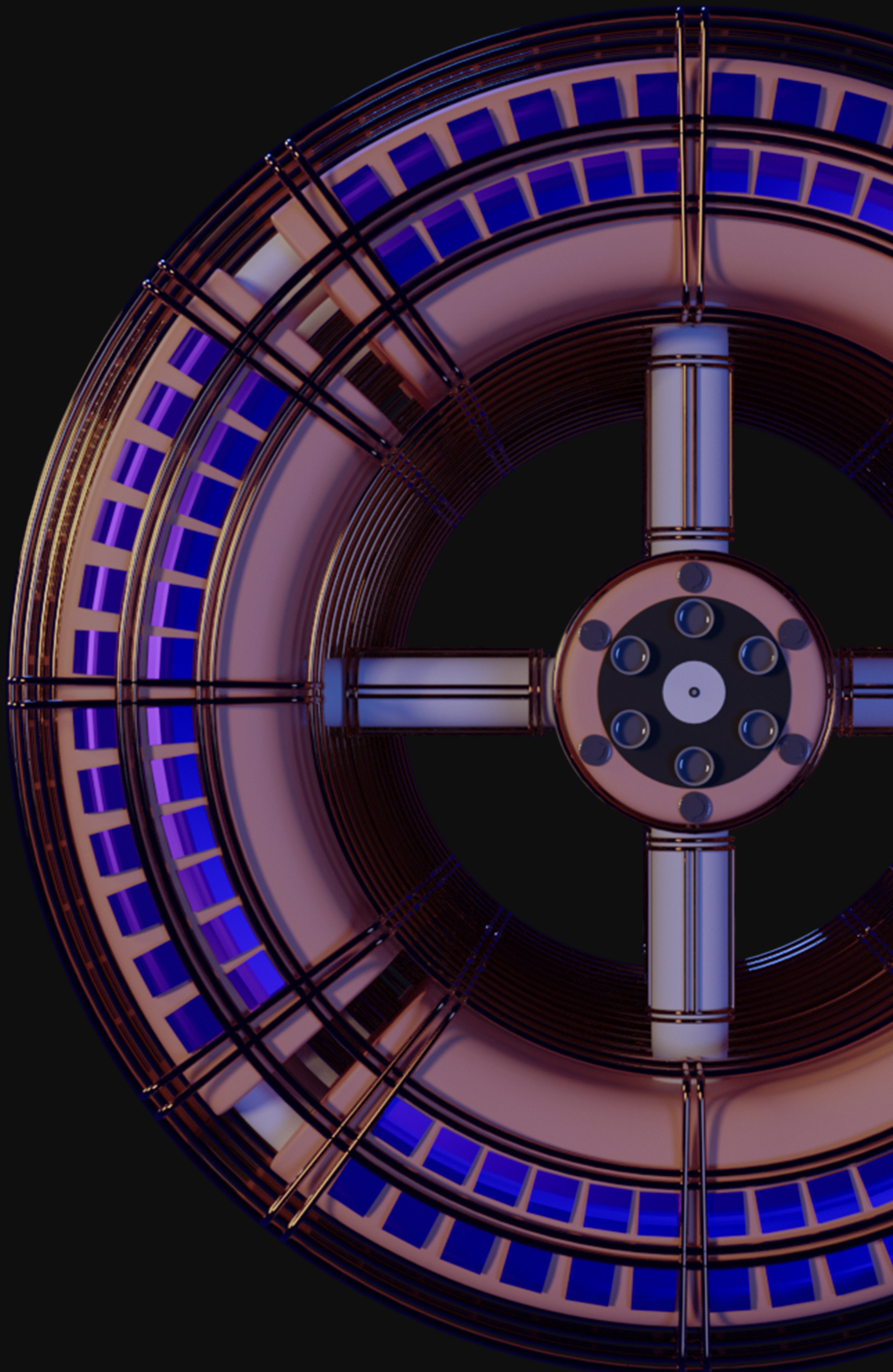
BENEVECTORAS

AMITY INTERNATIONAL SCHOOL, NOIDA, UTTAR PRADESH, INDIA



NORTH DONNING HEEDWELL

16th Asian Regional Space Settlement Design Competition
Team Data Form

Name of the primary teacher/advisor: Smita Fangaria

School (or other Group Name): Amity International School, Noida

School Address: Sector-44, Noida

School City, State, Zip or Postal Code: Noida-201303, Uttar Pradesh

Country: India

Daytime Telephone at School: 0120-4399000

Cellular or Mobile Phone: 9599058537, 8700076472

Fax: 95120-2431430

E-mail address: sfangaria@gmail.com

Names, [gender], and (grade/age) of 12 students currently expecting to attend the Finalist Competition: (we advise that participants be at least 14 years old, and not older than 19 as on July 31, 2019)

Name [gender](grade/age)

Akshit Sinha	[M](11/16)	Saanch Gupta	[F](11/16)
Jaskeerat Singh Sarin	[M](11/15)	Bhavya Goel	[F](11/16)
Kreetik Thakur	[M](11/16)	Kushagra Sharma	[M](11/16)
Aryan Arora	[M](11/16)	Dhruv Pandey	[M](11/16)
Nishchay Sinha	[M](11/16)	Sarvarth Dobhal	[M](11/16)
Sidak Taneja	[M](11/16)	Akshit Agarwal	[M](11/17)

Names of two adult advisors currently expecting to attend the Finalist Competition:

Smita Fangaria [F]   Anshu Agarwal [F]

I understand that if our Team qualifies for the Asian Regional Space Settlement Design Finalist Competition January 2020, we will be expected to finance our own travel to / from Om Shanti Retreat Center, Manesar and share the cost of boarding / lodging during the competition.

Smita Fangaria
Signature of primary chaperone/advisor

26-11-2019
Date

Index

1

EXECUTIVE SUMMARY

"To Infinity and Beyond"

— BUZZ LIGHTYEAR

NORTH DONNING HEEDWELL

BENEVECTORAS

FOUNDATION SOCIETY | NORTHDONNING HEEDWELL

SECURING YOUR TRUST. SHIPPING YOUR IDEAS.

Benevectoras bridges distances. Between Earth and Mars, between you and your vision. We comprehend every word of your requirement and after extensive research, we devised Benevectoras; a space settlement capable of delivering the finest from Mars while also functioning as a self sustaining community.

Northdonning Heedwell's formulation of Benevectoras is driven by your Perception and willingness to bring Earth and Mars closer in a profitable way. Functioning as a transport vessel intending to revolutionize trade in our system, Benevectoras integrates streamlined transportation with its industrial prowess to fulfil your vision.

Subtle differences in the functioning of Benevectoras come together to embody efficiency, comfort and speed.

The Docking stations contain a unique docking design featuring a large number of docks to allow transfer of CASSSCs from space tugs to transport channels at unprecedented rates, via a system of bridging tracks in Cargo Tugs, to the tracks present in the transport channels, making direct pathways that lead the CASSSCs to their allocated storage locations.

Benevectoras also allocates an immense proportion of its internal volume to CASSSC storage. Rapid loading and unloading, and ample storage spaces are a few of the key elements that contribute to increased productivity and swift transit, making Benevectoras the ideal cargo carrier.

Meticulous exploitation of resources at an extraordinary rate is the motto of Benevectoras. Deuterium is the future of power ships and Deuterium storage tanks present in the Spokes allow for isolation capability to help establish fusion powered transport.

Innovative industries thoughtfully placed according to their gravitational requirements allow Benevectoras to utilize all sorts of resources it can accumulate from Mars, Earth, as well as the microgravity conditions space itself presents, yet remains unparalleled in the services Benevectoras provides.

Each of the Space Tug designs encompass unique features- the hemisphere clamps of the Cargo tug for faster docking, the comfort provided by the Passenger Tug, and the powerful and efficient engines of the Propulsion tug- all optimize their efficiency in the multitude of tasks they take on.

Contract Awarded	7th May 2065
Customer Acquisition	End-2069
CASSSC storage volume	787,020.8 m^3
Gross Initial Investment	$42,857,385
Angular Velocity	1.2 RPM
Industrial Levels	0.24g-0.11g

We understand the Benevectoras you envisioned. We understand the multitude of tasks it must take on. That is precisely what our Benevectoras strives to be, to the point where your vision and our design are indistinguishable from each other

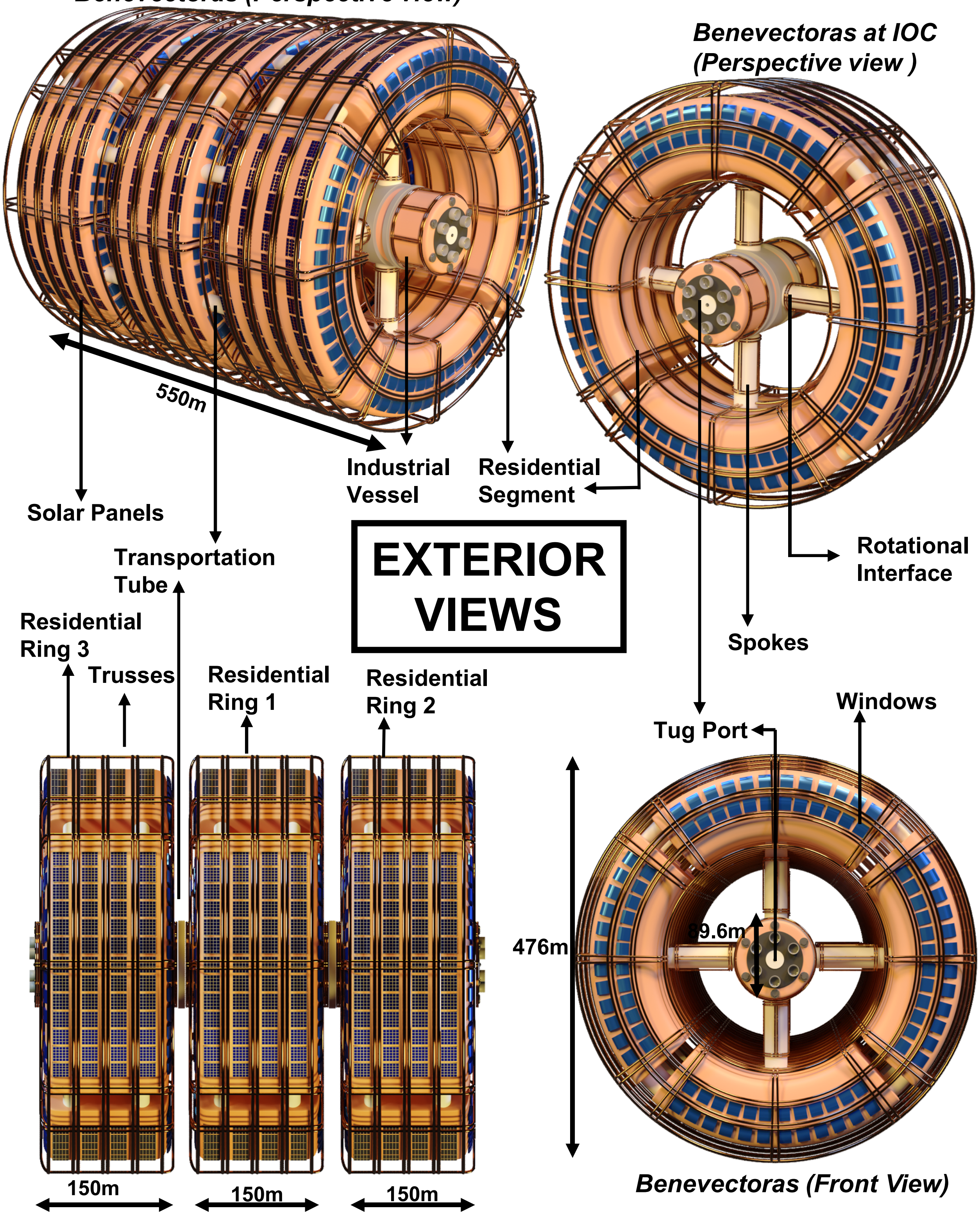
2

STRUCTURAL DESIGN

**“However well we build things,
it’s them that end up building us”**

NORTH DONNING
HEEDWELL

STRUCTURAL DESIGN



Benevectoras (Perspective view)

Benevectoras at IOC (Perspective view)

Benevectoras (Side View)

Benevectoras (Front View)

2.1 EXTERNAL CONFIGURATION

Table 2.1: *Major Sections*

Section	Pressure	g-level	Rpm	Radius	Key
Res. Rings	0.65atm	0.38g	1.2 rpm	236 m	
Industrial Vessel	0.65atm/ 0atm	0g	0 rpm	60.71 m	
Spokes	0.65atm/ 0atm	0.09-0.38g	1.2 rpm	40 m	
Docking Stations	0atm	0g	0 rpm	60.71 m	

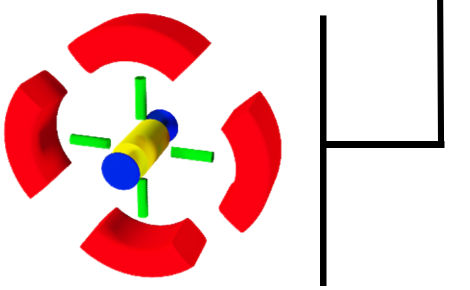


Figure 2.1.1: *Blown-Out*

2.1.1 RESIDENTIAL RINGS

At IOC, the residential area of Benevectoras will comprise of a ring structure(See Fig 2.1), consisting of 4 segments, providing a residential capability for 500 permanent and 1300 in-transit residents. At full operational capability, the residential area will expand to 3 residential rings to provide residential capabilities for 2500 full-time and 6300 in-transit residents.

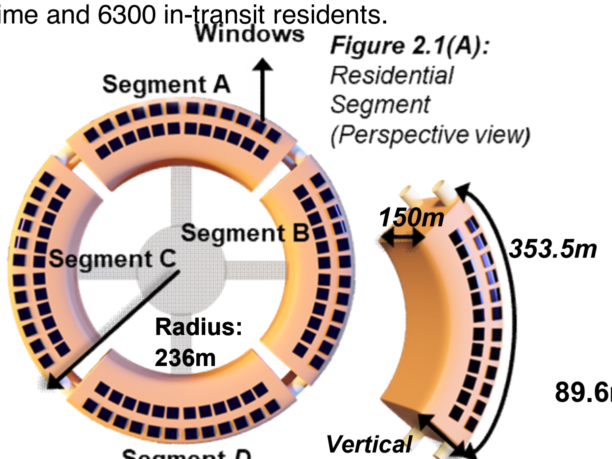


Figure 2.1(A): *Residential Segment (Perspective view)*

Figure 2.1(B): *Residential Ring (Front View)*

Windows are present on the peripheral side of the settlement(see Fig 2.1) to enable residents to enjoy stellar views of space, and of Earth and Mars when they are nearby.

All edges have been **beveled** to evade sharp points across the structure. The residential areas have a **uniform vertical clearance of 86m from the DSA to the roof of each segment.**

The residential rings are **rotating at 1.2rpm** to provide artificial gravity of **0.38g**.

2.1.2 INDUSTRIAL VESSEL

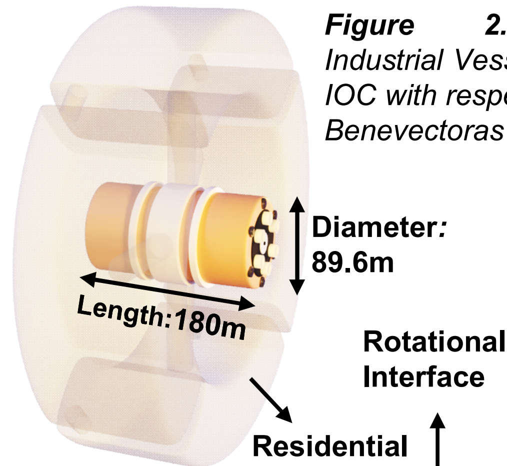


Figure 2.2(A): *Industrial Vessel at IOC with respect to Benevectoras*

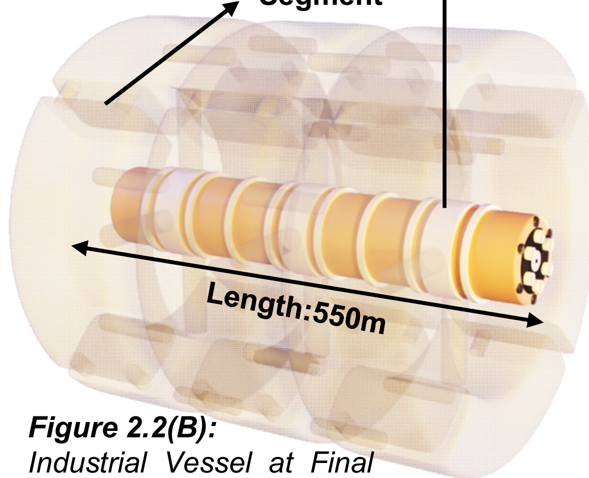


Figure 2.2(B): *Industrial Vessel at Final Operation Capability with respect to Benevectoras*

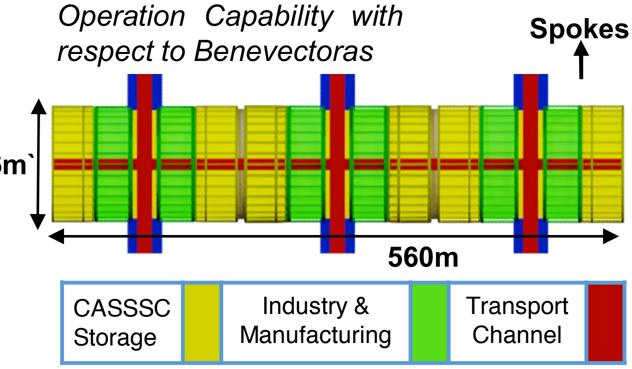


Figure 2.2(C): *Industrial Vessel Internal Configuration at Full Operational Capability*

The Industrial Vessel is a non-rotating cylinder present along the axis of rotation.
Facilities present in the Industrial Vessel include:

- **CASSSC Storage**
- **Manufacturing Areas [0atm]:** Manufacturing volumes providing capability for production of commodities and infrastructure(explained further in 2.5).
- **Space Tug Pushing Interfaces:** Interfaces present for space tugs to push on Benevectoras to perform course corrections. (explained further in 2.4).
- **Transport Channels:** Separate transportation for people and CASSSCs is provided throughout the Industrial Vessel
- **Space Tug Bays[0 atm]:** Storage for space tugs based at Benevectoras.

Addition Capability
(further explained in 2.3.2 and 2.5.1)

Residential and manufacturing capabilities are added to Benevectoras during the **assembly orbits**. **The Industrial vessel** is extended and **2** new **Residential Segments** are constructed on the extension during each assembly orbit. The already existing docking stations are subsequently converted to transport channels. Space Tug pushing interfaces(2.4.3) are constructed to provide **more locations for Space Tugs to push** for course corrections.

2.1.3 SPOKES[0.24g-0.12g]

The Residential Ring is structurally reinforced by 4 spokes at IOC, and 12 spokes at Full Operational Capability. These spokes link the residential segments to the Industrial Vessel, providing transportation for both CASSSCs and residents.

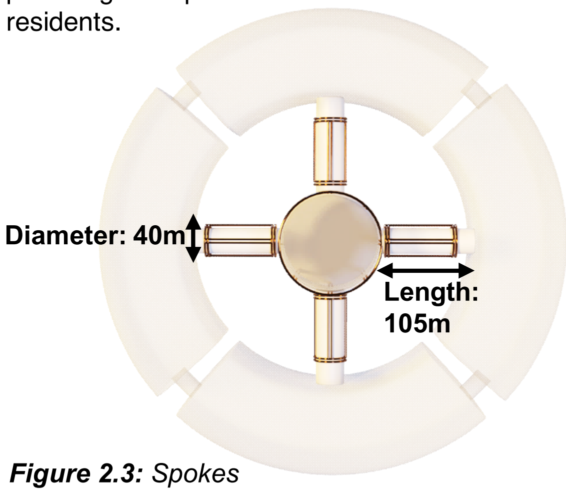


Figure 2.3: *Spokes*

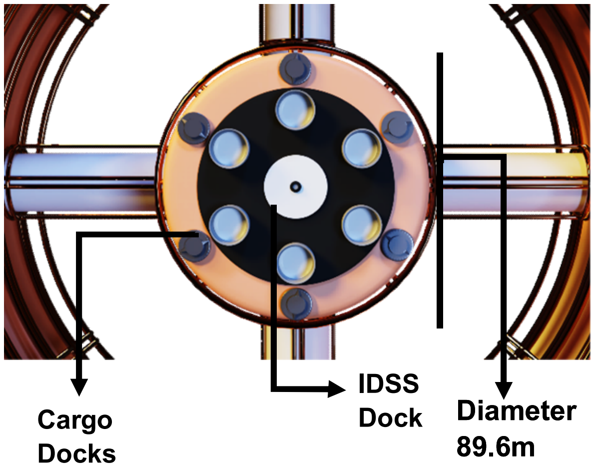
Spokes have also been used for:

- **Manufacturing and Industrial Areas (further explained in 2.5)**.
- **Waste Management**: Area required by the subcontractor **Toss It To Me** has been provided in the spokes.**(further explained in 3.2.4)**
- **Power Grids** and **Water Storage**
- **Transport Channels**: Easy Transport of CASSSCs and people from Residential Segments to Industrial Vessel.
- **Robot storage/ Tug Centre Control Room**
- **Deuterium Storage**

2.1.4 DOCKING STATIONS

Benevectoras has **2 Docking Stations (explained further in 2.4)** present at the ends of the Industrial Vessel (see fig. 2.4) which facilitate the **rapid transfer of people and cargo** during passes near Earth and Mars.

Figure 2.4: *Tug Port*



2.1.5 MISCELLANEOUS FEATURES

- **Solar Panels:** Solar Panels are present on the **outer curved surface of every Residential Segment** to fulfil the energy requirements of Benevectoras.
- **Truss System:** A truss system is present on **all exterior surfaces**, enabling **easy construction, repair and supervision** by means of the Out-Builder (further explained in 5.1.1). **Custom** trusses, of **radius 10 cm**, are used to facilitate movement of jigs, and are **subcontracted** to **Beam Builders, Ltd**.
- **Transportation Tubes:** Transportation tubes have been provided in order to increase inter-segment connectivity (explained further in 4.1.1).

2.1.6 ROTATIONAL INTERFACES

The interface between the rotating parts [Shown in RED] and non-rotating industrial vessel [Shown in BLUE] has been facilitated by **specialized cuboidal, angled grooves** (see fig. 2.5(A)) and ball bearings [Shown in GREEN] sandwiched together. **Both sides of the interface are unpressurised.**

The spoke connection plate is a cylinder with a diameter slightly larger than the internal cylinder to maintain a tight fit.

Transportation between the Rotating spoke and Industrial Vessel has been facilitated by a Vehicle (see fig. 2.5(B)) which is placed in the aperture between the end of the spoke and industrial vessel with its telescopic arms clamped to one side of the spoke. The **clamps** have been **proficiently designed** and comprise of an attaching-detaching mechanism that allows the vehicle to be at a relative velocity of zero to both the rotating spokes(rotor) and industrial vessel(stator).

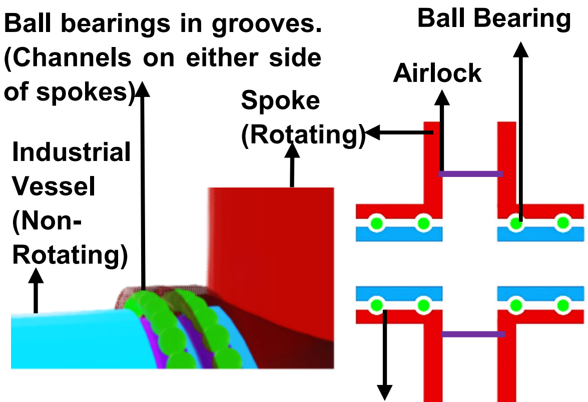
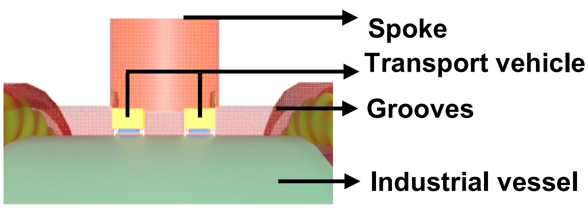


Figure Cluster 2.5(A): *Rotational Interface*

Industrial vessel *Cross-section*



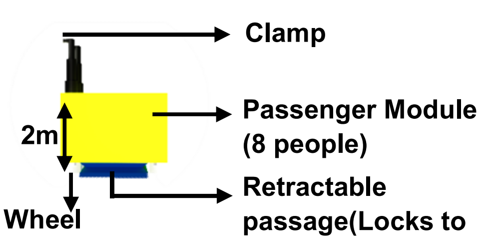
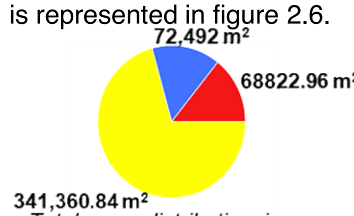


Figure Cluster 2.5(B): *Transport Vehicle*

2.2 INTERNAL ARRANGEMENT

2.2.1 RESIDENTIAL SEGMENTS

Residential segments include areas for residential and commercial purposes, and also provide various community services to the residents. The area allocated to various purposes is represented in figure 2.6.



Total area distribution in Residential Rings

Residential Area	Yellow
Commercial Area	Red
Community Services	Blue

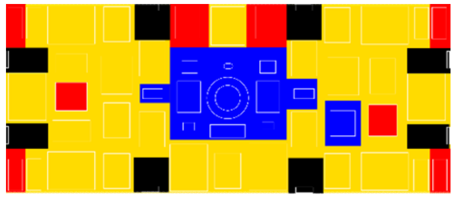


Figure 2.6(A): *:Area Allocation for one segment in Residential Ring 1, other segments identical.*

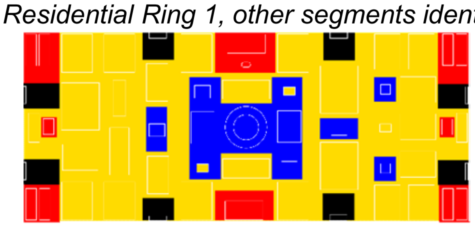


Figure 2.6(B): *:Area Allocation for one segment in Residential Ring 2 and 3, other segments identical.*

2.2.2 SPOKES

The area allocated to the various facilities present in the spokes is shown in figure 2.7

Industries (20,520 m²)	Green
Deuterium Tanks (16,416 m²)	Cyan
Waste Management (6156 m²)	Orange
Robot Storage/ Tug Centre Control Room(6,156 m²)	Blue
Water Tanks/Power Grid(12,312 m²)	Magenta

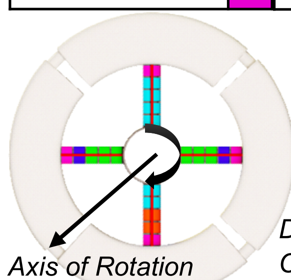


Figure 2.7(A): *IOC Configuration*

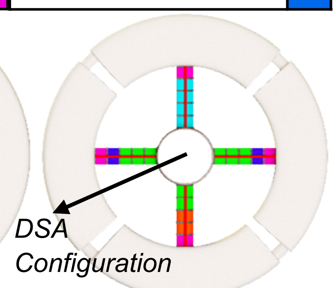


Figure 2.7(B): *Subsequent Configuration*

2.3 CONSTRUCTION PROCESS

Trusses are obtained from **Beam Builders Ltd.** Standard components (specified in 3.1) that are processed at Bellevistat are transported to Construction Location **(LEO)**.The processes required to construct Benevectoras are explained below.

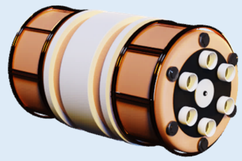
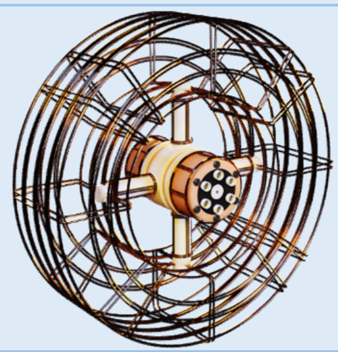
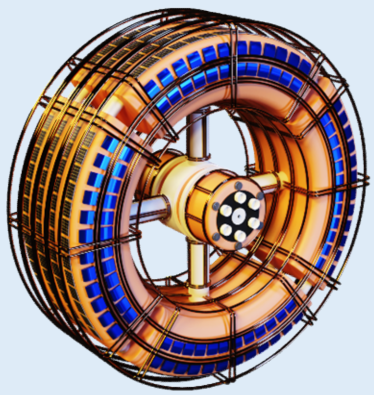
Phase	Process	Duration	Configuration
1	• **Construction Shack** set up and trusses of Industrial Vessel laid out. • External Construction robots deployed to construct the body of Industrial Vessel and docks.	2066 – 2067	
2	• Trusses of exterior structure of spokes and residential ring constructed **Setting up of Industries in spokes and industrial vessel completed**	2067 - 2068	
3	• External construction of the residential ring completed. • Interiors of residential ring built. **Rotation of 0.38g initiated** **Benevectoras can now welcome residents.**	2068 - 2070	

Table 2.2: *Construction to IOC*

2.3.1 POST-IOC CONFIGURATIONS

After reaching IOC, Benevectoras increases both its residential capacity and manufacturing capability(refer to box and table 2.3).
CASSSCs delivered during initial construction are used as Distribution Centers and Offices(mentioned further in 4.1)

<u>**Post-IOC construction**</u>

1st near-Earth pass

- Construction takes place on the Industrial Vessel to extend it.
- 2 Spokes are constructed on the extension
- Truss of Residential Ring is constructed
- 2 diametrically opposite segments(for symmetry about axis) are constructed.

2nd near-Earth pass

- 2 more spokes are constructed on the extension
- The remaining 2 segments are constructed to complete the Residential Ring.
- Transport channels are built between the segments in the new Residential Ring to ease the movement of residents.

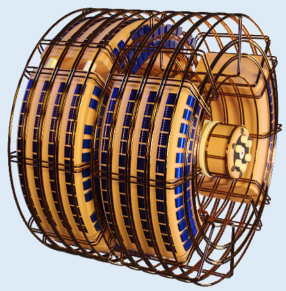
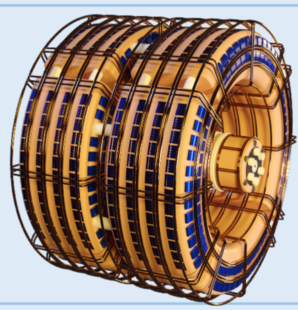
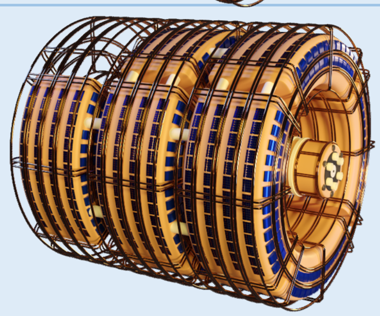
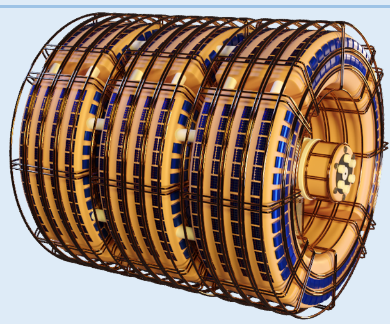
3rd near-Earth pass

- Construction takes place on the Industrial Vessel to extend it.
- 2 Spokes are constructed on the extension

- Truss of Residential Ring is constructed
- 2 diametrically opposite segments(for symmetry about axis) are constructed.

4th near-Earth pass

- 2 more spokes are constructed on the extension
- The remaining 2 segments are constructed to complete the Residential Ring.
- Transport channels are built between the segments in the new Residential Ring to ease the movement of residents.

Near-Earth pass	Configuration
1	
2	
3	
4	

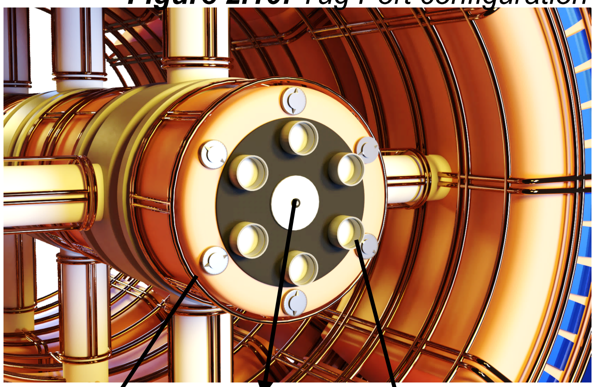
2.4 TUG PORT AND DOCKING FACILITIES

There are 3 types of space tugs based at Benevectoras to fulfill the need of course corrections and transport of cargo and people.(Further explained in 3.4)

2.4.1 TUG PORT

Docking Stations serve as the port for the fleet of Cargo and Passenger Space tugs arriving at Benevectoras. Each docking station contains 7 docks. 6 docks(**Radius: 6.9m**) for cargo tugs and 1 International Standard Space Dock for passenger tugs. There are 2 docking stations(at each end of the industrial vessel) resulting in a total of 12 cargo docks and 2 IDSS docks for passengers.

Figure 2.10: *Tug Port configuration*



The docks are widely spread out and are equipped with automated refueling and repair of the tug at the dock itself.

Figure 2.11: *Tugs docked at Tug Port*

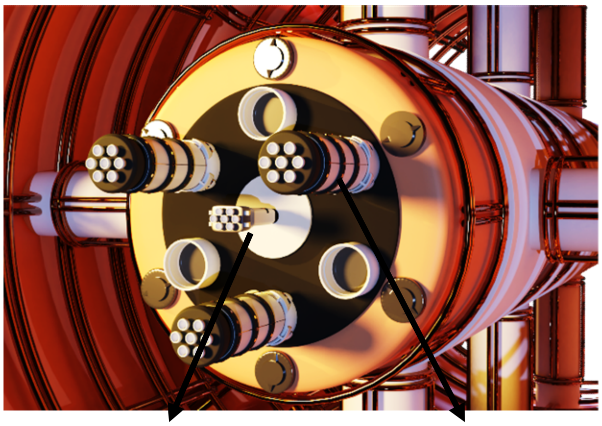


Figure 2.12: *Location of space tug ports(in BLUE).*

2.4.2 PUSHING INTERFACES

Interfaces for propulsion space tugs to push on Benevectoras are spread along the industrial vessel. The interfaces are arranged to ensure thrust in all directions required for course corrections of Benevectoras.

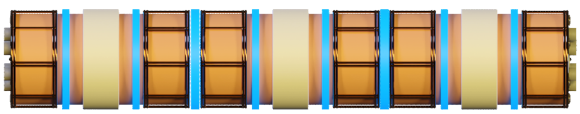


Figure 2.13: *Location of space tug pushing interfaces(in BLUE).*

Since the design for propulsion space tugs requires constant fuel propulsion space tugs stay docked on pushing interfaces to perform due course corrections. However for failure risk management, tug repair bots have been stationed beneath the surface of the main vessel for repair and storage of propulsion space tugs exclusively.

Figure 2.14: *Space tugs docked on pushing interfaces for course correction*

2.5 MANUFACTURING AND ASSEMBLY

Manufacturing capabilities which cater to residents as well as the Mars settles at Benevectoras exist in the Industrial Vessel as well as the Spokes. All capabilities in the **Industrial vessel** are **unpressurised** while those in the **Spokes** are **pressurised**

2.5.1 LOCATION ON EXTERIOR VIEWS AND INTERNAL MAP

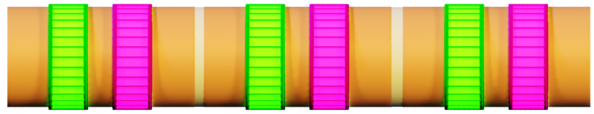
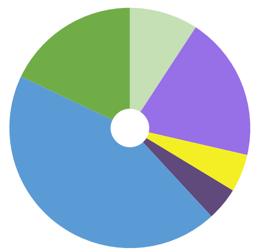
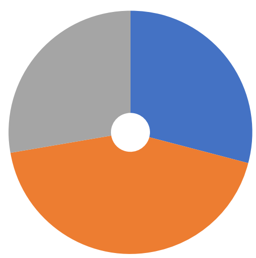


Figure 2.15: *Location of Industrial Vessel Manufacturing Volumes(in GREEN & PINK).*

Unpressurised Manufacturing Areas



GREEN Volumes



PINK Volumes

Aircraft rover area
Sabatier Methanation Reactors
Drones
Silicon Industry
Satellites
Assembly Area
Furniture and machinery
Toiletries
Kitchenware
Miscellaneous

Pressurised Manufacturing Areas

Ore Concentration
Food Processing
Polystyrene

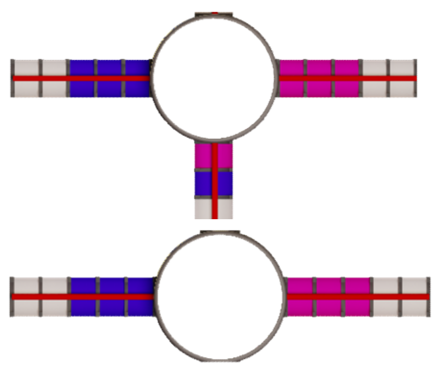


Figure 2.14: *Pressurised Manufacturing areas in the Spokes.*

2.5.2 ADDITION OF MANUFACTURING AND ASSEMBLY CAPABILITY

At every near-Earth pass during assembly orbits, **construction** of **additional manufacturing and assembly capability** takes place. Manufacturing areas are located in the Spokes as well as the Industrial Vessel to provide various g-levels to fulfill the requirement of different industrial process.

After prudently analyzing every requirement, we are eager to present an efficient and self-sufficient Benevectoras that goes beyond to provide you with a structure that caters to your necessities in every way imaginable.

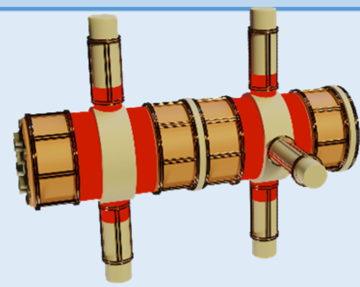
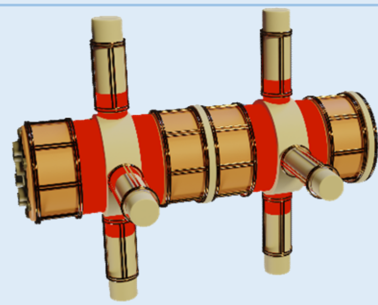
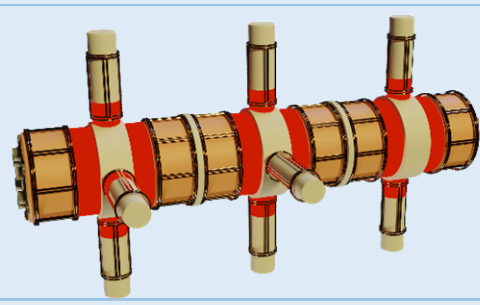
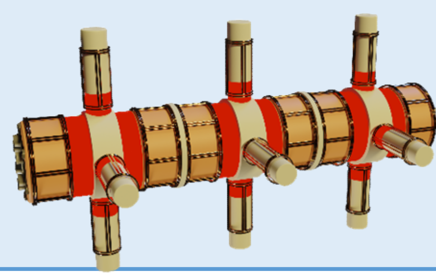
Near Earth Pass	Addition	Capability Enhanced	Configuration(Manufacturing areas shown in RED)
1	• Industrial Vessel expanded • Two spokes added	• All 0g Manufacturing areas • Food Processing	
2	• Two spokes added.	• All Pressurised Manufacturing Areas	
3	• Industrial Vessel expanded • Two spokes added	• All 0g Manufacturing areas • Food Processing	
4	• Two spokes added.	• All Pressurised Manufacturing Areas	

Table 2.3: *Addition of Manufacturing Capabilities*

3

OPERATIONS AND INFRASTRUCTURE

“Without planned execution, scribbles won’t turn to concrete”

NORTH DONNING HEEDWELL

OPERATIONS AND INFRASTRUCTURE

3.1 LOCATION AND MATERIALS SOURCES

3.1.1 CONSTRUCTION LOCATION

The construction location of Benevectoras would have major impacts on its intervention times in emergencies, initial exposure to radiation, the time taken to bring materials and structural integrity.

Keeping these factors in mind, we decided to construct Benevectoras **in Low Earth Orbit (LEO)** at an **altitude of 400km**.

- **Initial radiation protection** is provided by Earth's magnetic field.
- Proximity to the Earth **makes communication, as well as intervention in emergencies faster**.

Materials/ Sub-assemblies	Sources	Mass (kg)	No. of CASSSCs
Solar panels	ZAP!	206,453,957	**13,005**
Smart Dustbins	Earth	32,872	**2**
Windows	Belle vistat	869,165,358	**54,747**
Antenna	OLC	1,200	**1**

Table 3.1: *Operational requirements*

Materials/Sub-assemblies	Purpose	Sources	Mass (in kg)	CASSSC-loads
Titanium	Custom trusses for the frame	BeamBuilders, Ltd.	54,602,629	**3,440**
Aluminium	Building material for the hull	Alexandriat	4,128,963,474	**260,076**
Aluminium foam	Radiation protection and structural integrity	Alexandriat	1,268,296,350	**79,888**
Polyethylene	Radiation protection for windows, hull and solar panels	Bellevistat	299,779,137	**18,883**
Lunarcrete	Internal Building material for residential segments	Alexandriat	31,733,762,954	**1,998,852**
Buckystructures (Space debris protection)	Protection against space debris	BuckyBreakthroughs	2,899,992,547	**182,666**
Buckystructures (Thermal Insulation)	Thermal protection	BuckyBreakthroughs	1,933,328,364	**121,777**

Table 3.2: *Construction requirements*

Figure 3.1: *Materials packed in CASSSCs*

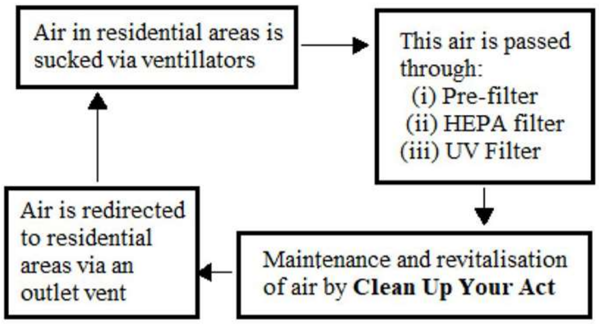
3.2 COMMUNITY INFRASTRUCTURE

3.2.1 ATMOSPHERE AND CLIMATE

The residents of Benevectoras will be provided with an atmospheric pressure of 0.65 atm. Both initial and subsequent quantities of air has been delegated to the subcontractor **Stuff of Life** and will be **carried in CASSSCs**. The maintenance as well as **revitalization of air** is carried out by the subcontractor **Clean Up Your Act**. Benevectoras will have the **same climate** throughout the settlement. **HVAC systems** controls humidity, ventilation, temperature and air conditioning. **Airlocks** are provided in segments for avoiding pressure fluctuations.

Gas	Partial Pressure	Mass of air (Initial Qty.) (kg)	Number of CASSSCs	Mass of air (Increase at every pass)(kg)	CASSSC-loads
Nitrogen	0.41374	6411919.1	**404**	5343265.92	**337**
Oxygen	0.21	3254466.6	**205**	2712055.5	**171**
Water Vapour	0.026	402933.96	**26**	335778.3	**22**
CO_2	0.00026	4029.3396	**1**	3357.783	**1**
Total			**636**		**531**

Table 3.3: *Mass, composition, quantity of air*



Flowchart.3.1. *Air circulation*

3.2.2 FOOD PRODUCTION

Benevectoras has been designed to minimize the need for the outsourcing of most agricultural products; nutritional variety in food produce has been ensured.

Meat and dairy are produced **using in vitro fertilization. Aeroponic techniques** have been

Integrated with **vertical farming,** there are **15 vertical stacks** present. **High Yielding Variety Seeds** are used to maximize disease resistance and improved nutrient absorption. **Water atomizing** is used to provide the plants with mist and nutrients. The nutrient intake is further monitored by laser sensors.

Photosynthetically Active Radiation (PAR) will be provided by LEDs in order to enhance plant growth. Plants are provided with growing conditions of: **Temperature:** 18°C - 28 °C **Humidity:** 40% - 80% **Pressure:** 0.65 atm. The agricultural section is divided amongst the residential segments with a small proportion of it in the parks for green spaces (cherries and strawberries) and beautification, as shown in residential plans in **4.1.**

Food Produce	Total Consumption (Kg)	Total Water Needed (L)	Land Needed (m^2)	CASSSC-loads
Wheat	99,360	16,394,400	13,413.26442	**7**
Rice	64,800	8,899,308	4,235.685724	**5**
Potato	13,392	211,392.72	1,359.028974	**1**
Fruits	103,680	4,687,372.8	7,060.27257	**7**
Vegetables	90,720	1,167,566.4	25,289.7659	**6**
Pulses	64,800	12,416,976	54,729.72973	**5**
Oats	25,920	1,563,883.2	4,073.142857	**2**
Meat	172,800	-	-	**11**
Dairy	34,560	-	-	**3**
	670,032	45340899.12	110160.8902	**47**

Table 3.4: *Initial Food Quantities and area*

Food Produce	Total Consumption (Kg)	Total Water Needed (Aeroponics) (L)	Land Needed (Aeroponics) (m^2)	CASSSC-loads (*-shared)
Wheat	82,800	13,662,000	11,178	**6***
Rice	54,000	7,416,090	3,530	**4***
Potato	11,160	176,161	1,132	**1**
Fruits	86,400	3,906,144	5,883	**6**
Vegetables	75,600	972,972	21,075	**5**
Pulses	54,000	10,347,480	45,608	**4***
Oats	21,600	1,303,236	3,394	**2**
Meat	144,000	-	-	**10**
Dairy	28,800	-	-	**2**
Total	**558,360**	**37,784,083**	**91,801**	**39**

Table 3.5: *Subsequent Food Quantities and area*

Thermoforming and **vacuum packing** in cold storage conditions increase shelf life to over 6 times higher than original life. The nitrogen flushed packed food is stored in CASSSCs around the Spoke Entrance Area(elaborated upon in **4.1) The Farmdroid (3.2)** includes claws to plant seeds, a scythe to harvest crops, and a sensor on the underside to monitor their health, so they may be tended to. The farmdroid can move laterally on both axes.

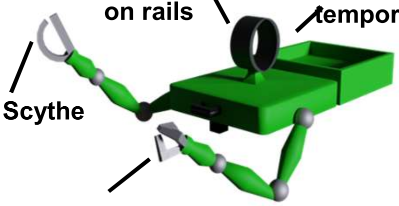


Figure 3.2: *Farmdroid*

3.2.3 WATER MANAGEMENT

Water is provided by the subcontractor **Stuff of Life; Clean Up Your Act** recycles water and returns potable water. **Vacuum toilets**, **water atomizing in showers and faucets,** bring down water consumption to 57.145 L per person per day. **40m³** tanks store water for each segment. These tanks are placed inside the spokes

3.2.5 ELECTRICAL POWER GENERATION

The primary source of power on Benevectoras, is solar power. At any given instant, a minimum outside area of 162,758.62 m^2 of the settlement faces the sun. Since the entirety of the external surface area is covered in solar panels provided by **ZAP! Industries**, this results in an output of 141,012.58 kW, while Benevectoras initially requires only 92100kW (as shown in **Table 3.6**). Excess power is stored in a power grid of **Li- ion** located in the **Spokes**, to account for instances when a particular segment doesn't face the Sun. As segments are added, solar panels increase.

Use	Requirement Initial Quantities (kW)	Requirement Increase at every pass (kW)
City Facilities	6,517	6,010
Residential Needs	1,402	1,090
Lighting	5,300	4,416
Industries	31,661	31,661
Automations	42,682	42,679
Total	92,100	91,109

Table 3.6:*Electricity requirements*

Table 3.7: *Water requirements*

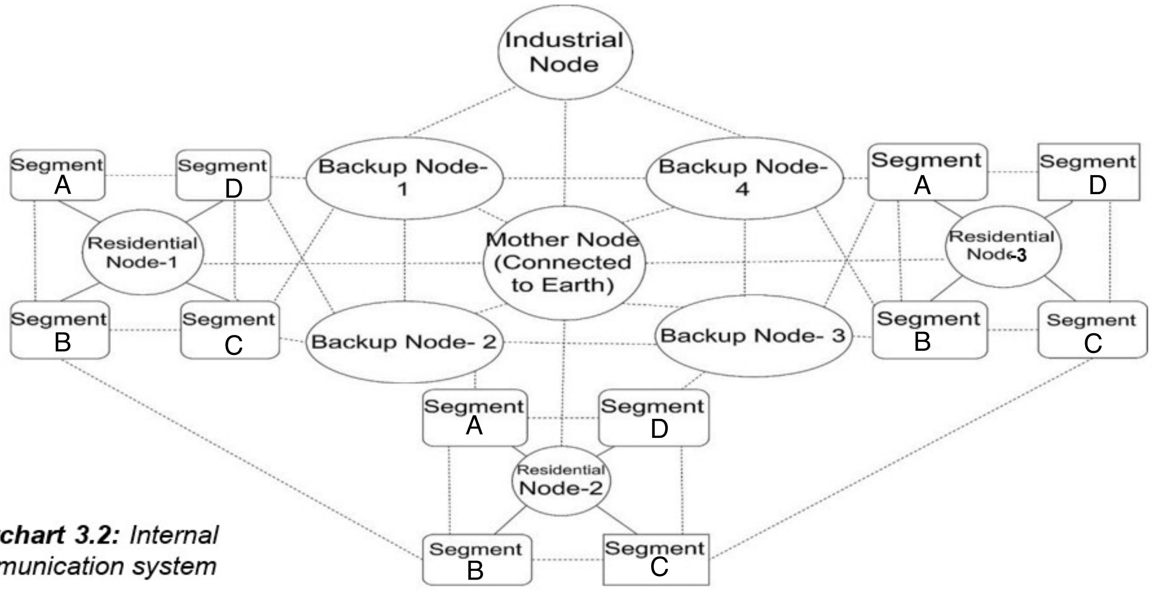
Use	Requirement Initial Quantities (L)	CASSSC Storage	Requirement Increase at every pass (L)	CASSSC-loads
Residential	102,727	**7**	85,606	**6**
Agriculture	45,340,899	**84**	37,784,082	**70**
Industries	316,592	**20**	28,811	**18**
Misc.	100,000	**7**	90,000	**7**
Backup	112,748	**8**	94,432	**6**
	45,972,967	**126**	38,342,932	**107**

3.2.4 HOUSEHOLD AND INDUSTRIAL SOLID WASTE MANAGEMENT

Toss It To Me and **Waste Products** function in a consortium to manage recycling of trash and sewage systems respectively. **1100 m²** of landfill area in the spokes has been provided to Toss It To Me and a similar area for a building where the conversion process occurs has been provided in each segment. An unpressurised area in the **Industrial spokes** has also been provided as per their requirements. **Smart dustbins** are utilised for the segregation of waste. **3-D scanning systems identify** and segregate waste into paper, plastic and wet waste.

3.2.6 COMMUNICATION SYSTEMS

For internal communication, a node-based network mesh will be used which is responsive and quick. It uses nodes which are interconnected via a 6g network to increase response time(0.2μs) and bandwidth(1Tb/s). It creates a network mesh hence reducing network blind spots or hotspots. External Communication will be done **via Free Space Optics (FSO)** which has a data transfer speed of **1Tbps** (Terabits per second). The settlement also has **relay capability** which stores data until proper connection is established. Receiving of signal will be done by **antenna** established by sub-contractor **OrbitLink Communications**.



Flowchart 3.2: *Internal Communication system*

3.2.7 INTERNAL TRANSPORTATION SYSTEMS

Automated shuttles are used for internal transportation, each with a capacity of **8 passengers**. There would be a total of 48 shuttles (**4 in each segment**). These shuttles also **enable commute** between adjacent residential segments **via transportation tubes**. The use of bicycles is promoted which aids in **maintaining the fitness of the residents**. **Nearly 510 bicycles per segment** would be available for use inside the settlement.

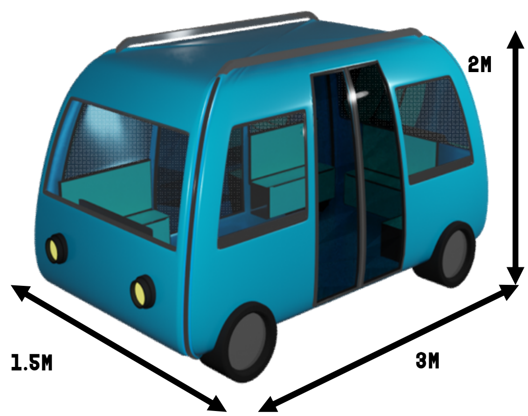


Fig.3.5: *Shuttle*

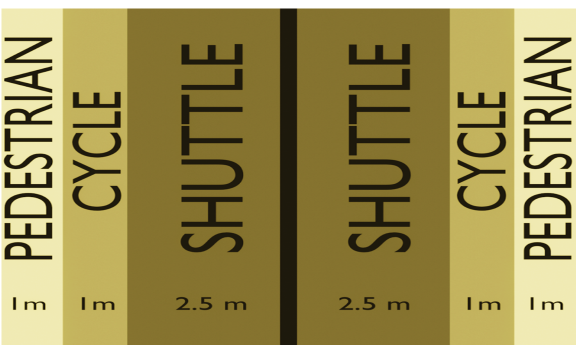


Figure 3.3. *Road map*

Fig.3.4:Cycle

3.2.8 DAY/NIGHT CYCLES

While natural sunlight enters via the **windows** present between the divisions of the segment, light is primarily provided **artificially**. **Lead infused electrochromic glass blocks** sunlight and the intensity of the artificial light is turned down when night time needs to be simulated.

Time Duration(hrs)	Light intensity(W/m^2)
0000 – 0400	0 – 50
0400 – 0800	50 – 200
0800 – 1200	200 - 375
1200 – 1600	375 – 250
1600 – 2000	250 – 50
2000 - 2400	50 – 0

Table 3.8. *Light intensity throughout the day*

3.3 CONSTRUCTION MACHINERY

In order to make all internal and external construction faster and more efficient, all machinery has been incorporated **into the ExCon and InCon** (explained in **5.1)** These units would be carried in standardized CASSSCs brought to the ship by space tugs.

Trusses are joined to form an exoskeleton for Benevectoras upon which the hull will be constructed. Same assets will be used for internal as well as external construction

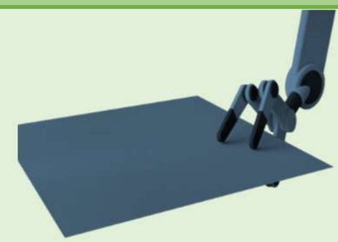
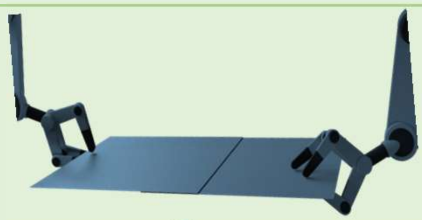
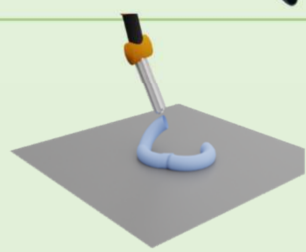
Machinery	Description	Figure	Sub-Assemblies/Material component operated
Robotic claw	Lifts and loads materials		Aluminium foam panels, Titanium truss, Buckystructures panels (debris protection and thermal insulation variant)
Frictional-stir welding claw	Welds material together (cold welding for vacuum, frictional for internal)		Aluminium panels, Titanium (truss system), Aluminium Foam
Buckystructure Adhesive Dispenser	Dispenses adhesive		Polyethylene (on thermal Buckystructure) and Buckystructures
Polisher	Smoothens and polishes rough surfaces		Aluminium, Titanium, Lunarcrete
Cutter	Cuts according to required size		Lunarcrete, aluminium panels, Aluminium Foam, Buckystructures

Table 3.9: *Machinery for internal and external construction*

Standard Components	Dimensions (m)
Aluminium Panels	6m x 3m sheets 0.12 m thickness
Titanium Trusses	9m length 0.2m Diameter
Buckystructure(Thermal Insulation Variant)	6m x 3m sheets 0.12m thickness
Lunar Crete	1m x 1m sheets 0.2m thickness
Polythene (made into rolls for accommodation in CASSSCs & ExCon)	500m x 1.1m sheets rolled up. 0.8m diameter of roll 0.0001m thickness
Aluminium Foam	6m x 3m sheets 0.12m thickness
Buckystructure(Debris Protection Variant)	6m x 3m sheets 0.12m thickness

Table 3.10: *Standard Components*

Jigs **traverse through the truss** and help in the movement of the **ExCon across the settlement**. They are present in between two trusses.

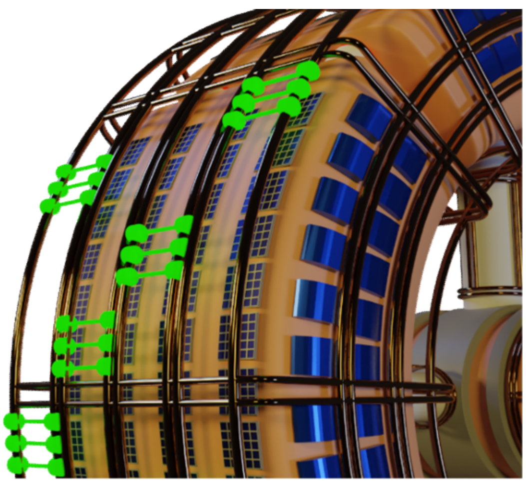


Fig 3.6:*Jigs*

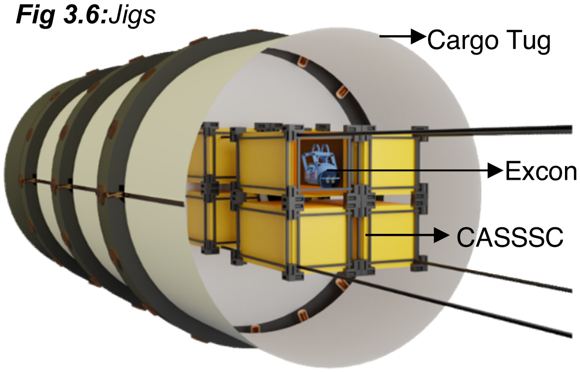


Fig 3.7: *Construction machinery shipped in CASSSCs via space tugs*

3.4 SPACE TUGS AND CASSSC WAREHOUSING

3.4.1 CASSSC WAREHOUSING

CASSSCs carrying cargo are stored in **vertical layers 2 CASSSCs wide**, thus allowing access to all individual CASSSCs.

PRIOR TO TRANSFER OF CARGO

All empty CASSSCs present in the settlement do not have any empty layer present between them as specific CASSSCs do not need to be accessed. Here no vacant layer is present between CASSSCs.

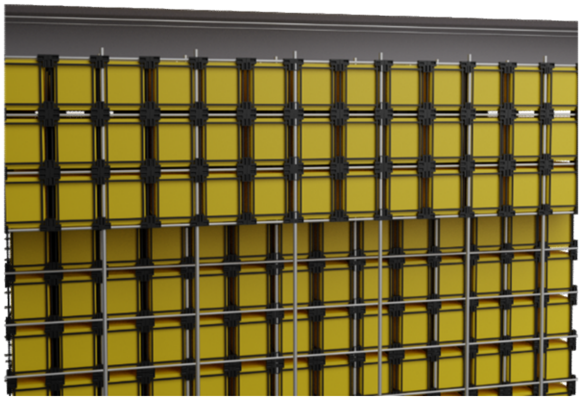


Fig.3.8. *Empty CASSSCs storage prior to transfer of space tugs*

AFTER TRANSFER OF CARGO

CASSSCs after transfer of space tugs as well as CASSSCs storing some cargo prior to transfer of space tugs have a vacant layer between them, thus allowing access to specific CASSSCs and enhancing their transport by moving them to the vacant layer and redirecting them to the transport channel.

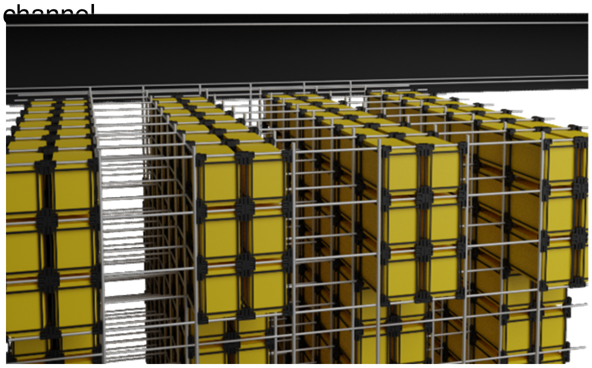


Fig.3.9 *Storage of CASSSCs after transfer of space tugs as well as CASSSCs storing cargo for settlement*

3.4.2 SPACE TUGS

Manoeuvring Benevectoras, forming the link between Benevectoras and in orbit passengers and cargo: the Space Tugs based and Benevectoras and perform a multitude of tasks that are crucial to its functioning. Therefore, their design inculcates specific features that allow them to effectively execute the tasks they are designed to carry out.

Table 3.11. *Space tugs*

<table>
<tr><th>Type of Space Tug</th><th>Diagram</th></tr>
<tr><td>

Passenger Tugs: The passenger tugs are capable of carrying **90 people** at a time. It is **24.255m** long, with a **LOX-LH2** fuel tank of **408 m³.** The tug consists of levels, with **8 seats** on each level, and a **central channel** that allows movement between the levels. There are a total of **12 levels**. The seats are laid horizontally to the levels.

Numbers at IOC-**4**
Numbers after completion-**10**

<table>
<tr><td>Seats (Horizontal, 170cm x 95cm)</td><td></td></tr>
<tr><td>Channel (106cm x 186 cm)</td><td></td></tr>
<tr><td>Storage</td><td></td></tr>
</table>

Key

</td><td>

Fig 3.10: *Passenger space tugs*

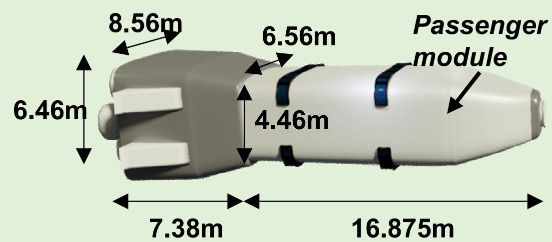
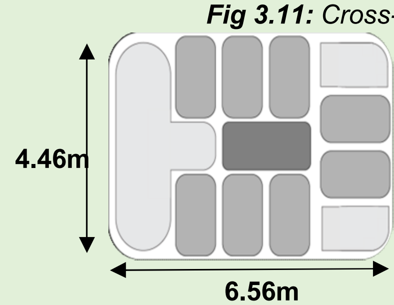


Fig 3.11: *Cross-Sectional View*



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<tr><td>

Cargo Tugs: A **LOX-LH2** fuel tank of **958.44 m³** has been provided. The cargo tug carries 12 CASSSCs. The corner sleeves (further elaborated upon in **5.4**) of the CASSSCs **are fitted onto rails on the inside** of the tugs. After the hemispherical top retracts to help in docking, these **rails align** perfectly with those of the docks to allow **direct transfer** of CASSSCs from the docks to the storage.
Numbers at IOC-**12**
Numbers after completion-**22**

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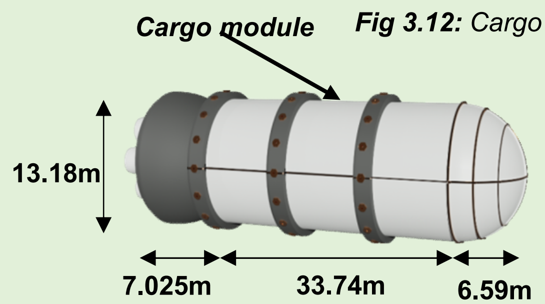
Fig 3.12: *Cargo tugs*



</td></tr>
<tr><td>

Propulsion Tugs: A **LOX-LH2** fuel tank of **134.65 m³** has been provided. The propulsion tugs employs an extremely powerful engine to allow for course corrections and manoeuvring of Benevectoras. The lower half consists of a **small fuel tank** and a **docking base**, as well as an **outlet for refuelling**. While the tug is capable of moving in isolation, it is almost always **docked on the pushing interfaces**. It only needs to be moved to the tug repair stations or dispose off when broken.

Numbers at IOC-**32**
Numbers after completion-**96**

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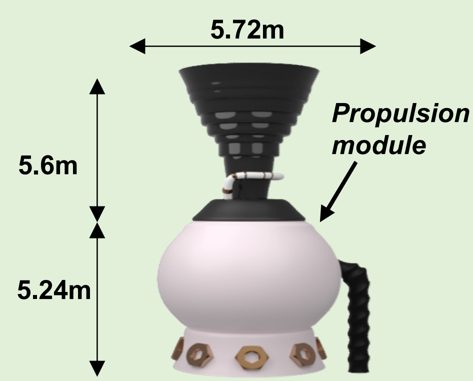
Fig 3.13: *Propulsion Tugs*



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</table>

3.5 MARS INFRASTRUCTURE

After careful examination of the role Northdonning Heedwell plays in the development of Mars infrastructure, as well as the services we can provide and the resources Mars settlers have at their disposal, we advise the provision of the **following infrastructure** to accelerate their development and cater to their major needs. **All infrastructure items will be provided in sub-assemblies** so that they can be **shipped in CASSSCs.**

Infrastructure	Reason
Sabatier Methanation Reactors	**Abundance of CO_2** on Mars makes it ideal for having Sabatier methanation reactors to produce methane which could be used **as a fuel for rockets and other vehicles**.
Rovers	They provide **access to difficult and uneven terrains** and could also help in **locating resources**.
Aircrafts	They help to provide transport of **both cargo and passengers** in Mars.
Drones	Powerful drones will be made that can fly on the Martian surface and **could aid in research, reconnaissance, transport as well as delivery of goods**
Fiberglass for greenhouse	Fiberglass for greenhouse is provided to grow crops. They **scatter light and provide diffusion** and can last for a long time.
Fiberglass for windows	It helps in **insulation and in the maintenance** of exterior structure. It will help windows be **light weight** and make operations easier.
Fiberglass in aerospace industry	It is **incombustible and has dimensional stability**. It can be used in the industry for **test equipment, ducting, enclosures, engine cowling and bulkheads**.

Table 3.12 : *Surface Infrastructure*

Infrastructure	Reason
Communication Satellites	Communication satellites are provided in order to **establish efficient communication** on Mars
Weather Satellites	These satellites could help **in predicting dust storms** on Mars.
GPS Satellites	They will help establish a **Global Positioning System** on Mars.
Reusable Launch vehicles	It will **reduce cost** by repeatedly making use of **new use and throw launch vehicles**. It also **decreases the growing space debris**.

Table 3.13. *Orbital Infrastructure*

The infrastructural requirements, both surface and orbital, are synonymous to economic growth and development. With reference to your requirement, we advice and manufacture (refer to 7.3) the above infrastructure specially curated for the settlers of Mars while exploiting the resources available judiciously.

4

HUMAN FACTORS AND SAFETY

“Safety first is safety always”

NORTH DONNING HEEDWELL

HUMAN FACTORS AND SAFETY

Benevectoras ensures that its residents, in-transit settlers and business officials are provided with all the comforts, facilities and services present in.

PROVISIONS FOR NATURAL VIEWS

We understand the need to provide the residents of Benevectoras with **stellar views of space** as to ensure that people feel uncongested and free. In order to cater to this need, **windows have been placed on the hull**. The composition of windows are given below in table 4.1.

Lead Infused Glass	Radiation Absorption
Silica Aerogel	Low Density Insulator
Poly-ethylene	Solar Flare Radiation Protection
Poly-ethylene	Solar Flare Radiation Protection
Aluminum Oxynitride	Tensile Strength
Electrochromic Glass	Regulation of light intensity

Table 4.1: *Windows Composition*

4.1 COMMUNITY DESIGN

4.1.1 TRANSPORT SYSTEM

Communities in Benevectoras are strategically planned to provide residents with all the amenities, services and maximum comfort.

Intra-ring transportation is provided by **2 transportation tubes** present at the **ends of the segments**. **Inter-ring transportation** is also provided by similar transportation tubes that run **along the sides of the segments.**

The transportation tubes provide easy and efficient movement between all the segments in Benevectoras. Each segment contains a **number of parks** which provide a **number of green spaces, open areas** that provide a better quality of life for the residents.

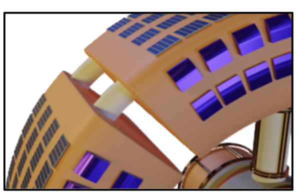


Figure 4.1: *Intra-ring transportation*

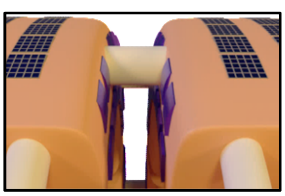


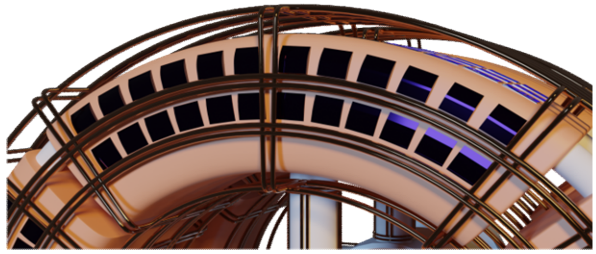
Figure 4.2: *Inter-ring transportation*

4.1.2 LIST OF FACILITIES

Hospitals (Total Area: 2,000 m²):

- They contain **surgical bots** which can perform all major surgeries along with organ replacement without the need for human intervention.

Figure 4.3: *Windows Location*



- The IOC hospitals will also act as **medical research facility in 0.38g.**

School (Total Area: 400 m²):

- The educational zone is placed in one segment of the initial ring **(segment A of ring 1)**. The education zone comprises of a school and a university.

SpaceKart Distribution Services (Total Area: 4,328 m²):

- The residents aboard Benevectoras can enjoy the benefit of **door-step delivery** with the **SpaceKart** distribution service. The SpaceKart distribution centers are present **around the spoke entrances**; they also act as an entrance to the **elevator system** to reach the main industrial vessel.
- CASSSCS will contain shelves and vertical sections, which will be **used as storage containers** of SpaceKart centres.
- The **DelivKart** (Detailed in 5.1) is used for delivering daily products to the residents which they can order from their home through their **SmartBand,** (Detailed in 5.3) etc. and reach them within a reasonable time.

Gymnasium (Total Area: 1,500 m²):

- Provided to **maintain their health** while their stay in low gravity.

Malls and Community centers (Total Area: 11,100 m²):

- Malls and Community centres are present in every segment of each ring; they include general stores, retail stores, restaurants, etc. They also provide **recreational activities** to residents to promote **interaction amongst them.**
- **The Grand Space Casino**, **VR arcades**, movie theatres, library and **sports simulators** are present inside malls and community centers.

<u>Green spaces/Parks:</u>

- Parks and aeroponic shelves are distributed throughout the residential segments**. Parks and the arc of the structure** both add up to provide residents with **open spaces and long lines of sight.**
- Parks and landscaping soil will be *subcontracted to Soil Solutions*; parks will contain **edible plants** like **cherries and strawberry bushes.**

4.1.3 COMMUNITY PLAN

(dark green)	Vertical Aeroponics Stacks
(light grey)	Type I (Permanent) *
(brown)	Type II (Permanent) *
(blue-grey)	Type III (Permanent) *
(yellow)	Type IV (In-transit) *
(light green)	Type V (In-transit) *
(cyan)	Distribution Centre and Spoke
(magenta)	Automation Services

Table 4.2: *Key I*

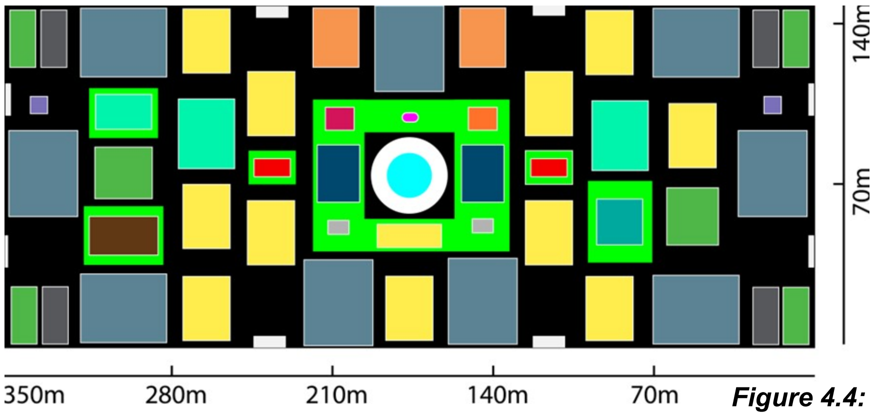


Figure 4.4: *Community Plan (Ring 1)*

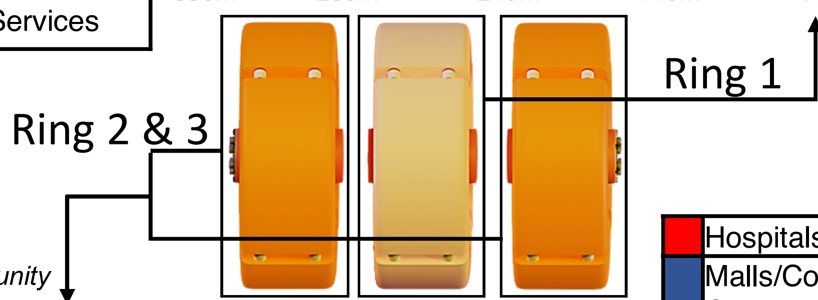
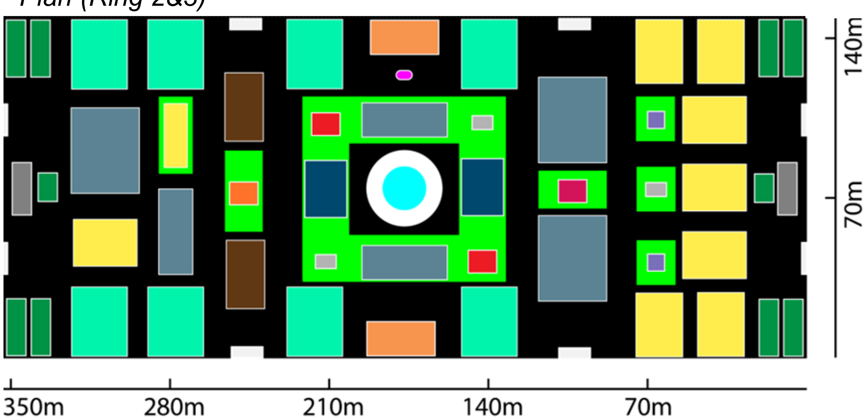


Table 4.3: *Key II*

(red)	Hospitals
(dark blue)	Malls/Community Centers
(light orange)	Office
(teal)	Educational Zone
(orange)	Government Buildings
(crimson)	Gymnasium
(green)	Parks
(lavender)	Shuttle Repair
(white)	Airlocks
(grey)	Spacesuit/Blown Storage areas

Fig. 4.5: *Community Plan (Ring 2&3)*



4.2 RESIDENTIAL DESIGNS

There are a total of **5 house designs** to meet the housing requirements of the permanent as well as in-transit population. There are a total of **4,715 houses**, each floor with a vertical clearance of **3.3 meters**. The tallest buildings have **3 floors with a height of 10 meters, all the buildings have a vertical clearance of 262.4 feet (80 m) above them.**

The windows of all houses are made of **polymer-dispersed liquid crystals glass** which can **control the intensity of light** that is let through. To provide the residents with maximum views of the surrounding community, **only one apartment is built on each floor**. The stairs have an **adjacent ramp for wheelchairs**, **1 wheelchair is provided** near each neighborhood for disabled residents

Figure 4.6 shows the configuration of various houses which form **a neighborhood of similar of type houses**; this is done to create the feeling of togetherness.

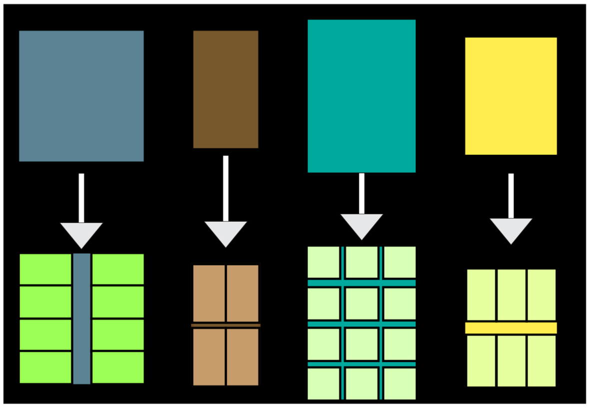


Table 4.4: *Configuration of each type of house*

Figure 4.6: *Configuration of houses (Ring 1)*

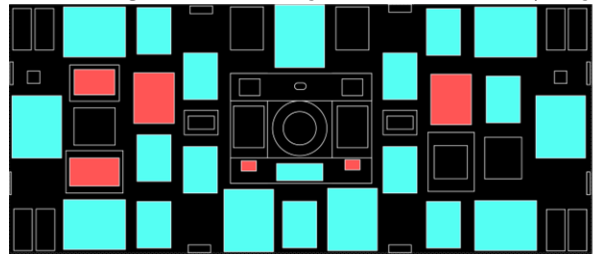


Table 4.5: *Key*

In-Transit	
Permanent	

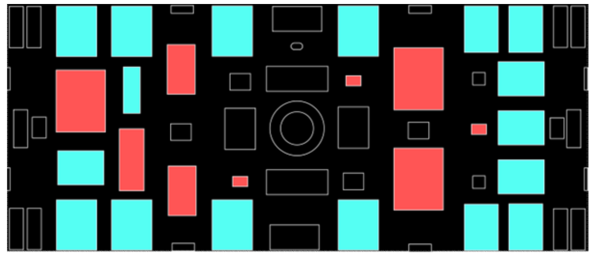
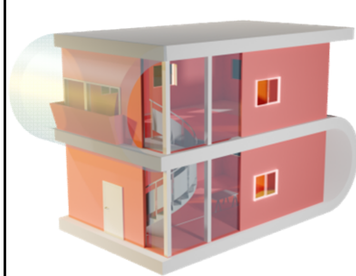
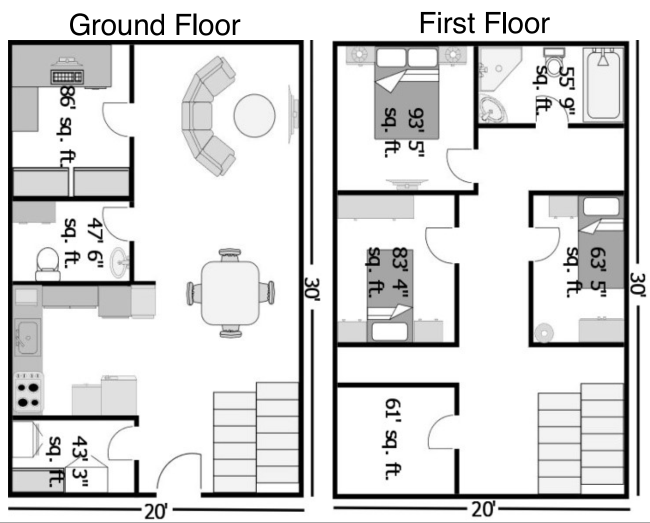
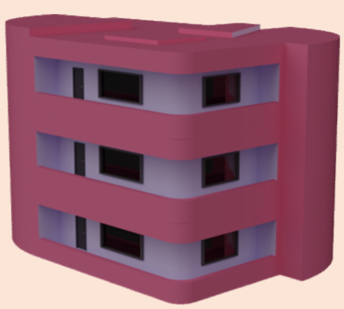
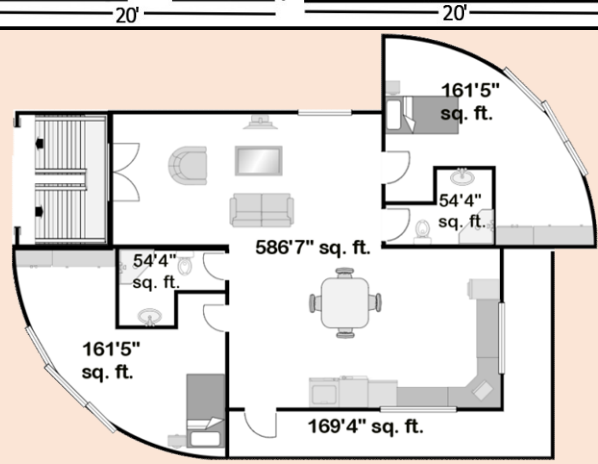


Figure 4.7: *Configuration of houses (Ring 2&3)*

4.2.1 HOUSE DESIGNS

Specifications	Exterior Design	Interior Plan
<u>Type I</u> 3 Bedrooms, 2 Bathrooms, a balcony **Area**: 1200 sq.ft. **Quantity**: 35 Houses (2 Floors)	 Height: 21.6 ft	
<u>Type II</u> 2 Bedrooms, 2 Bathrooms, a balcony **Area**: 1187' 5" sq.ft. **Quantity**: 450 Apartments, 80 Buildings (3 Floors)	 Height: 32.8 ft	

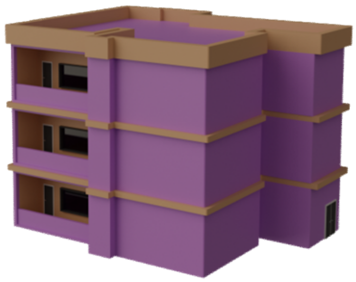
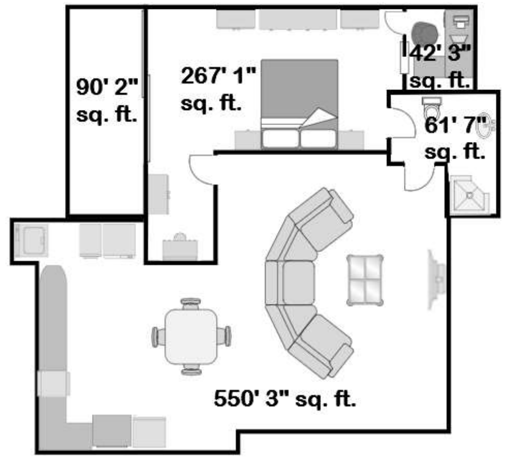
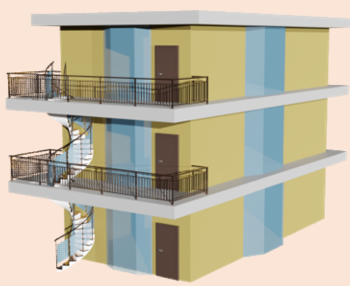
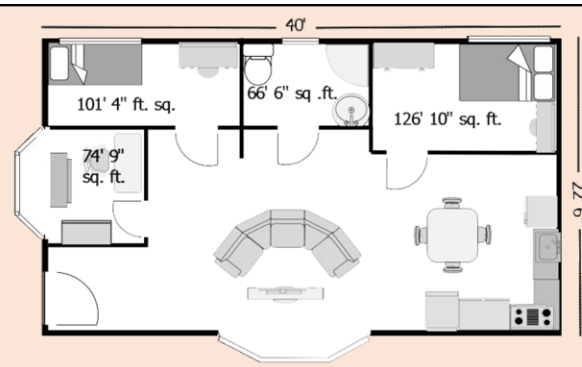
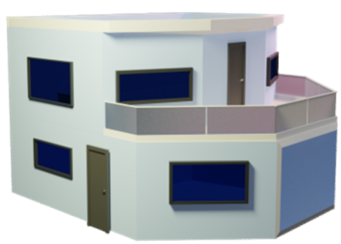
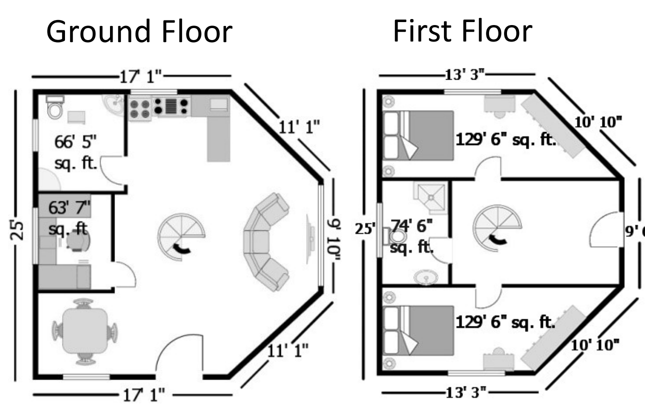
Type III 1 Bedroom, 1 Bathroom, a balcony **Area:** 1011' 4" sq.ft. **Quantity:** 1190 Apartments, 400 Buildings (3 Floors)	 Height: 32.8 ft	
Type IV (In-Transit) 2 Bedrooms, 1 Bathroom **Area**: 900 sq.ft. **Quantity**: 1921 Apartments, 642 Buildings	 Height: 32.8 ft	
Type V (In-Transit) 2 Bedrooms, 2 Bathroom, a Balcony **Area**: 1100 sq.ft. **Quantity**: 1279 Apartments (2 Floors)	 Height: 21.6 ft	

Table 4.6: *House Designs*

4.3.1 ISOLATION CAPIBILITY

- In an unlikely event of an **emergency** causing damage to a particular residential zone, the **tubes will help carry out evacuation** and subsequent isolation owing to the provision of airlocks as well as portable emergency shelters **subcontracted to EST.**
- During an evacuation, spacesuits will be transported from nearby segments to fulfill the number of spacesuits for that segment via the DelivKart. Technologies and temporary Living spaces will be **subcontracted to Blown Away**.
- Each **Ring 1 segment will have 234 spacesuits** and each **Ring 2 & 3 segment will have 251 spacesuits.** Sizes for space suits are available for both children and adults.

4.2.2 SPACESUITS

Quantity: **3400 suits**
All spacesuits will be subcontracted to EST.
456 Spacesuits will be reserved in airlocks across the settlement.

Spacesuit Features / Essentials

Rebreathers: Convert exhaled CO_2 to usable O_2

Communications: Communication systems are **present in a pouch** attached on the torso of the suit.

Visor: The visor is gold lined **for protecting the operator's eyes from the Sun's rays** and has a **display** which shows the O_2 level, condition of the suit and more.

Pressure retention: Urethane coated Nylon, Dacron and layers of Spandex are used for pressure retention.

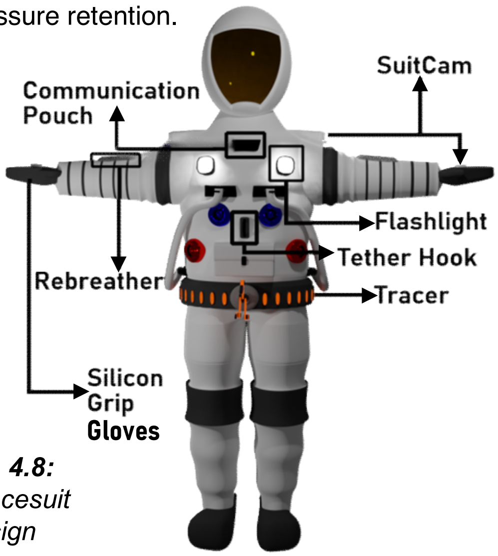


Fig. 4.8: Spacesuit Design

4.3.3 SAFETY DEVICES

- **Handrails:** Are made of titanium, available in **variable sizes (10m-30m) depending on the location to assist in mobility and are** located along the **exterior surface** of Benevectoras and outside airlock in **zero gravity areas.**
- **Tethers:** For maintaining contact and safety of the operator, space suits are equipped with a **tether hook** which connects the operator to Benevectoras or the **EVA module** via tethers, which are *subcontracted to Bucky-Breakthroughs.*
- **SAFER:** They are positioned **inside EVA** airlocks. The operators can wear SAFER while going for EVA/repair, **the EVA modules will also contain SAFER.**

Table 4.7: *Spacesuit Layers*

Layer	Purpose
Liquid Cooling Ventilation Garment	Regulates body heat and keeps the astronaut cool **(Innermost)**
Mylar	Temperature stabilization and radiation protection
Teflon coating	Provides strength, durability
Beta Cloth	Protection from X-rays, Gamma Rays, Beta Rays
Kevlar	Shock absorption, heat resistance
Bright white fabric	Prevents penetration from space debris, subcontracted to BuckyBreakthroughs **(Outermost)**

- **Suitcam:** Placed **behind the palm** and on the **shoulder** of the suit, Suitcam helps the operators carry out EVA in relatively **inaccessible areas.**
- **Grips:** The gloves of the suit contain **silicon grips** *subcontracted to BuckyBreakthroughs* to provide friction, allowing the glove to **avoid slipping and provide better grip** when needed.
- **Tracer:** A belt which has a **small retractable tether (5m in length)** which **hooks on handrails** allowing secured movement on the **rotating interface** and the industrial vessel.

Fig. 4.9: *Tracer*

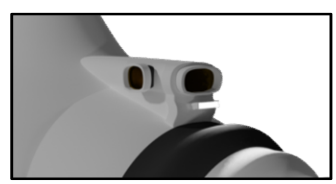


Fig. 4.10: *SuitCam*

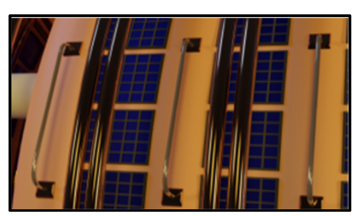


Fig. 4.11: *Handrail Designs*

4.3.4 EVA MODULE

- The Ex-Con will be made of three connected parts- the **construction module, storage module and the EVA module**.
- The EVA module will be able to function independently and will be tele-operated and autonomous, it has **tether modules** which connect tethers to the spacesuit of the operator working on the external rotating surfaces. The entire EVA module will be **pressurized** so that the operator can use the control panel without wearing the spacesuit.
- The entire front made out of **radiation protected glass** and is **tilted downwards** so that the operator can inspect for repairs on the rotating surface of Benevectoras. It is equipped with **screens and control panel** for controlling robotic arms for major repairs and for checking the surveillance system.
- The Ex-Con will move on the truss, a **duct retracts down from the EVA module and attaches to the airlock** allowing for easy and rapid access for the Operator to enter and exit the EVA module. The module is equipped with a room for **donning and doffing of space suits.**

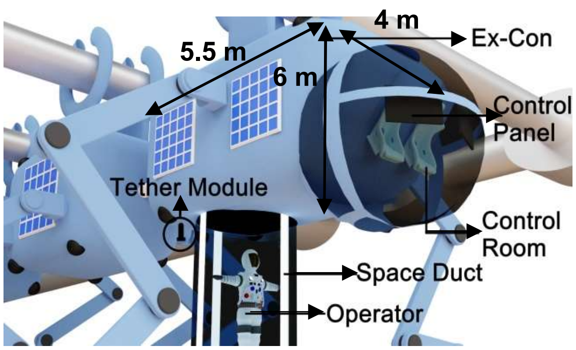


Fig. 4.12: *EVA Module*

4.3.5 AIRLOCKS

All airlocks are *subcontracted to Lossless Airlocks*

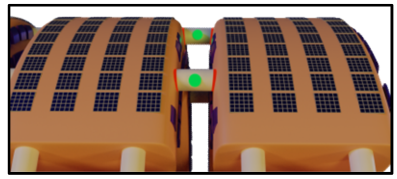
<u>EVA airlocks:</u>

- Will be positioned on the **sides of the 2 transportation tubes linking residential segments of different rings**. They will be positioned **opposite to each other** in order to **maximize area coverage.**
- The IDSS Dock - from where the residents enter Benevectoras- have **modified 10-people airlocks** to add to the comfort and efficiency.

<u>IVA airlocks:</u>

- Will be positioned on the **ends of all the transportation tubes**. There will also be an airlock positioned in the **pressurized room** (Detailed in 7.1) present in the industrial vessel which connects to the elevator.
- Airlocks for CASSSCs are also provided adjacent to the pressurized room to provide **CASSSC transportation** between the industrial vessel and the residential zone.

Fig 4.13: *EVA/IVA Airlocks*



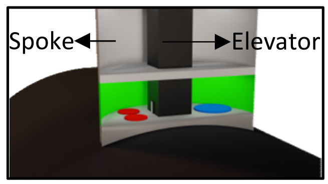


Fig 4.13: *Pressurized Room Airlocks*

	EVA Airlock
	IVA Airlock
	CASSSC Airlock

Table 4.8: *Key*

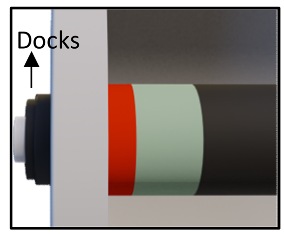


Fig 4.13: *IDSS Dock Airlock*

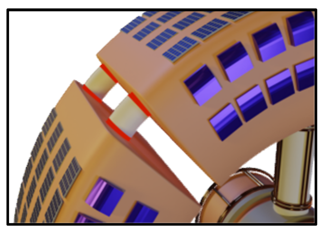


Fig 4.16: *IVA Airlocks*

4.4.1 COMMODITIES MOVEMENT SYSTEM

- CASSSCs are fitted with **Corner Sleeves** (further in 5.5) that comprise of **retractable clamps and linking mechanisms** on alternate corners of each side of the CASSSC. The Corner Sleeves allow the **fast omni-directional movement** of CASSSCs on the tracks.
- These tracks connect the **main CASSSC storage with the space tug docking area and the industries.** The industrial goods produced in industry are placed inside the CASSSCs via **retractable arms**; the CASSSCs are further transported on the tracks with the help of **corner sleeves to the main storage inside the industrial vessel.**

- With the track system connected, the CASSSCs are **directly positioned inside the space tugs** when required to ship goods to Mars settlers.

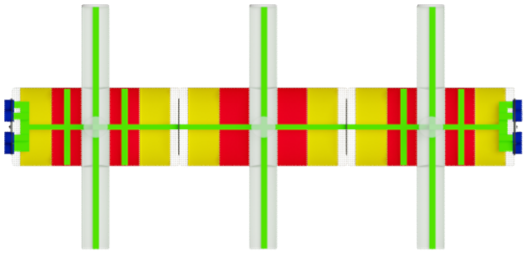


Fig. 4.17: *CASSSC Track Route*

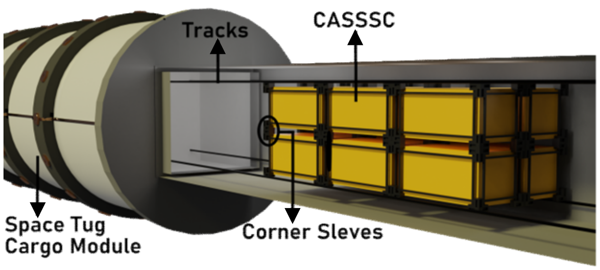


Fig 4.18: *Transportation of CASSSCs*

- The space tugs are capable of holding up to **12 CASSSCs** and is directly connected with the track system as shown in figure 4.19.

Fig. 4.19: *Industrial Vessel Configuration*

Table 4.9: *Key*

Main CASSSCs storage	Industries
Docking Station	Track System

4.4.2 PRODUCTION OF DAILY COMMODITIES AND EXPORT

Amount of **daily commodities** that are produced and exported for both; residents of Benevectoras and mars settlers are listed below in the table

Commodities	Amount (per person per year)	Mars Settlers (Every Mars Pass)	Produced
Toiletries			
Toothpaste	6 tubes (1.02 kg)	6,000 (1020 kg)	Benevectoras
Tooth brush	4	4000	Benevectoras
Shampoo	5 bottles (1.25 kg)	5000 (1250 kg)	Benevectoras
Conditioner	5 bottles (1.25 kg)	5000 (1250 kg)	Benevectoras
Razor Blades	4	4000	Benevectoras
Towel	2	2000	Benevectoras
Toilet Paper	100 Rolls	100000	Benevectoras
Body Wash	12 bottles	12000	Benevectoras
Lotion	4 bottles	4000	Benevectoras
Medical Kit			
Bandages	30	30000	Benevectoras
Gauze Dressings	4	4000	Benevectoras
Tweezers	1	1000	Benevectoras
Sterile Gloves	4	4000	Benevectoras
Scissors	1	1000	Benevectoras
Thermometer	1	1000	Benevectoras
Epinephrine Auto injector	1	1000	Benevectoras
Antiseptic Cream	4	4000	Subcontracted
Painkillers (Ibuprofen, Paracetamol, Aspirin)	25 tablets	25000 tablets	Subcontracted
Kitchen Ware			
Plates	3	3000	Benevectoras
Bowls	3	3000	Benevectoras
Glasses	3	3000	Subcontracted
Cutlery	4 packages	4000 packages	Benevectoras
Pots and Pans	3	3000	Subcontracted
Cutting board	1	1000	Subcontracted
Ladle, Whisk and Spatula	3	3000	Subcontracted

Wearables			
Clothes	5.78 kg	5780 kg	Earth
Shoes	1.27 kg	1270 kg	Earth
Watch	1 watch (per person)		

Table 4.10: *Commodity List*

4.5: OFFICES

- We understand the need for adaptability of offices to accommodate different types of businesses according to the requirements of the in-transit Mars settlers' pursuits. Thus, to address this, the workspace will have mobile walls that can be moved throughout the office to make different businesses subdivided into required categories as per one's wish.
- To ensure optimum utilization of resources, the office buildings can be constructed by stacking CASSSCs together
- Offices are located in every residential zone to provide the in-transit and permanent residents with working space to continue their work and business during their stay in Benevectoras. These offices also **communicate with the industries** present in the industrial vessel for the production of goods and infrastructure required by Mars settlers to start their business on Mars.
- All offices are **located near the spoke entrance** in the residential segments so as to provide easy access to the main storage and the space tugs docks present in the industrial vessel. Other systems are provided like the Office A.I. to increase the overall productivity of the offices (elaborated further in 5.3).
- All the in-transit residents have a **home office** present in every house which allow the residents to continue their business while living in the comfort of their home.
- The offices span over a total **area of 3,096 m² in the Ring 1 segments and an area of 2,700 m² in the Ring 2 and 3 segments.**
- The offices of the permanent and in-transit settlers are separated as shown in figures 4.20 and 4.21 as the permanent and in-transit residents will have different businesses and the in-transit offices are temporary and will change periodically.

These offices include:
- A reception
- A conference room- for regular meetings, follow-ups
- Personal cubicles
- Cabins
- Storage areas- storage of office usage articles
- Utility rooms- for common office machinery
- A Canteen

Cabins will have smart glass walls so that the employees have their privacy in their hands.

Fig. 4.20: *Offices in Ring 1*

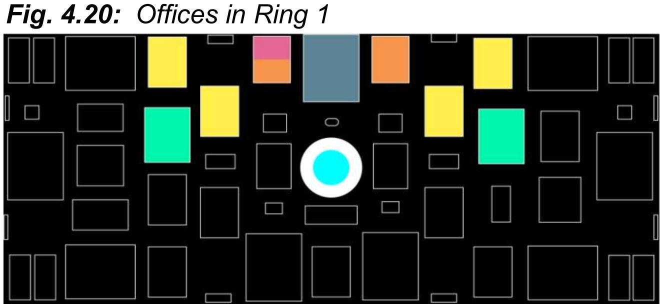


Table 4.11: *Key*

	Permanent Offices
	In-Transit Offices
	In-Transit Houses (Type IV)
	In-Transit Houses (Type V)
	Permanent Offices
	Spoke Entrances

Table 4.12: *Key*

	Permanent Offices
	In-Transit Offices
	Permanent Offices
	In-Transit Houses (Type V)
	Permanent Houses (Type II)
	Spoke Entrances

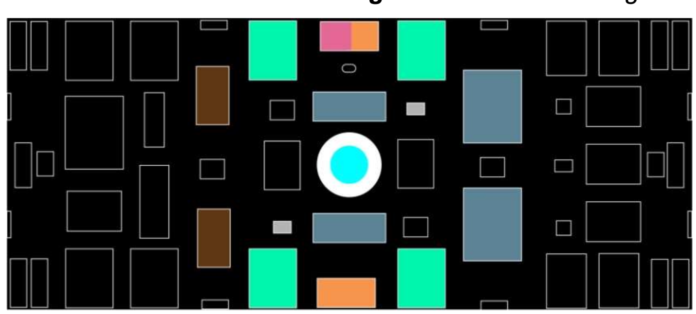


Fig. 4.21: *Offices in Ring 2&3*

5

AUTOMATION DESIGN AND SERVICES

“Creating helping hands to cater to your every need”

NORTH DONNING HEEDWELL

AUTOMATION DESIGN AND SERVIES

We, at **Northdonning Heedwell** have designed efficient and ingenious construction equipment and facilities to ensure **expeditious** and **safe** construction and assembly of Benevectoras.

All devices are equipped with **silicon photonic chips** that form the base of all internal circuitry used on Benevectoras.

5.1 AUTOMATION OF CONSTRUCTION PROCESSES

NAME	FUNCTION	SYSTEM
Raven	Facilitates construction activities on and in the settlement	Excon Incon
Eagle	Facilitates with maintenance and repairal activities	Excon Incon
HavOk	Facilitates inspection of the settlement	Excon Incon

5.1.1 EXTERNAL CONSTRUCTION

The **Excon,** the **modular robotic system**(with each module capable of operating independently) responsible for construction of the exterior of the settlement,.consisting of three modules:-

1. **The storage module**
2. **The construction module**
3. **The EVA module**

It is built on a **titanium-aluminium exoskeleton,** further reinforced by ***silicon-buckystructures,*** equipped with a **frictional stir welder** for welding metal sheets and has **solar panels** as its primary power source with **graphene batteries** as backup.

Software:- **Raven**

Data storage:- 10 petabytes

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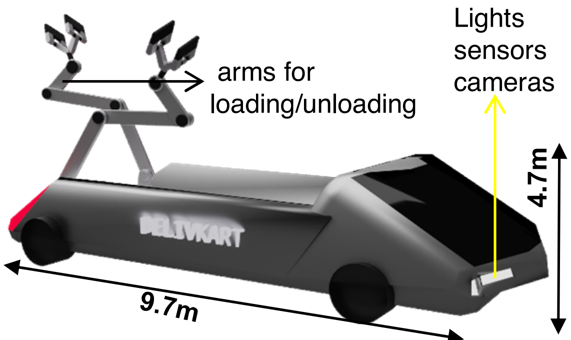


Figure 5.3: *DelivKart*

5.1.3 TRANSPORT AND DELIVERY

Transportation of raw material and goods on the exterior of the Benevectoras will be carried out by **the Storage module**. On the interior of the Settlement Delivkart will be used to carry raw materials and goods.

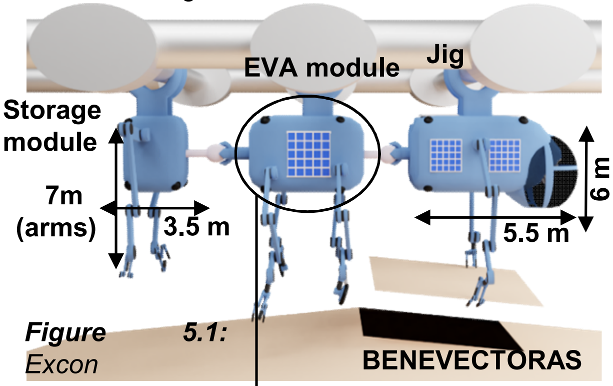


Figure 5.1: *Excon constructing Benevectoras*

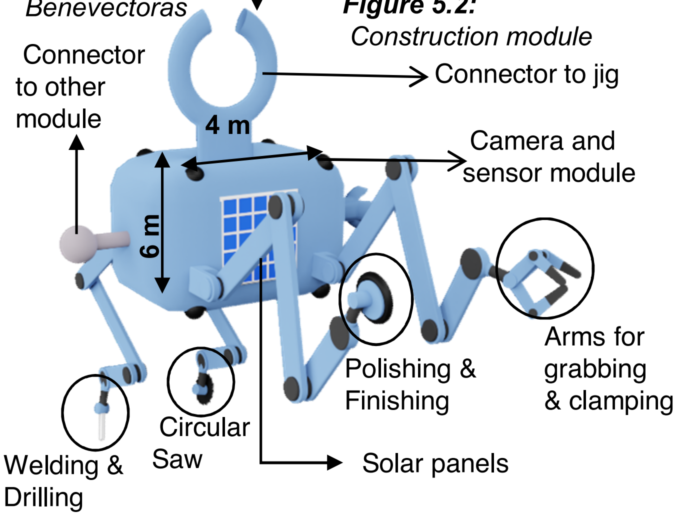


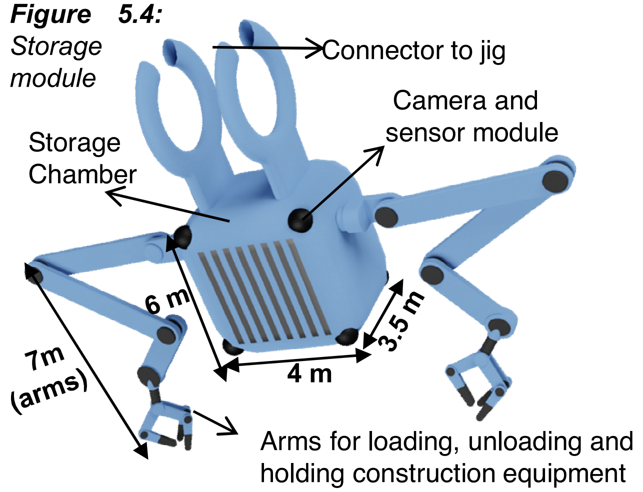
Figure 5.2: *Construction module*

5.1.2 HUMAN INTERACTION

The **EVA Module** is used by the **Operators** to carry out **monitoring and inspection of the exterior** of Benevectoras. It is equipped with a retractable space duct for easy access.

The Operators in the control room can also **tele-operate** the Excon using **HavOk.**

Figure 5.4: *Storage module*



5.1.4 INTERNAL CONSTRUCTION

The **Incon** carries out all interior construction & finishing processes. Equipped with **5 arms, 2 of them being smaller for interior finishing.** It has interchangeable arm-heads for maximum flexibility of handling fragile material .It contains storage space for the various tools and arm heads for rapid construction and maximum efficiency. It uses **graphene batteries** as its main power source and is provided **recharging stations.** The personalisation software **CIDS**(Custom Interior design software) allows residents to personalise fine details for **interior finishing** .
Software:- Raven
Data storage:- 10 petabytes

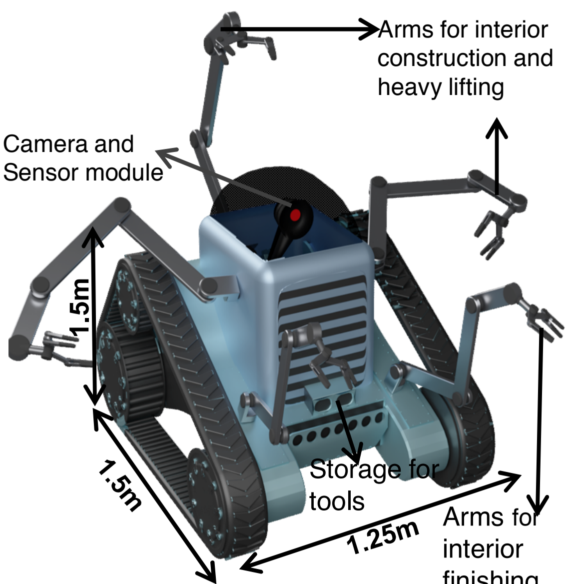


Figure 5.5:*Incon*

5.1.5 List of automation systems for settlement operations and construction

Automation System	Stored in	Quantity (At IOC/ at full operational capability)
Excon	Spokes	124/372
Incon	Spokes	168/504
EVA	Spokes	12/36
DelivKart	-	15/45

Table 5.2:*Automation systems for Operations and construction*

5.2 FACILITY AUTOMATION

Automation Systems present aim at preventing and/or minimizing any and all contingencies that the settlement may be susceptible to. For higher efficiency and aversion to human errors, most of the systems will be automated and governed by supercomputers.

5.2.1 SAFETY FUNCTIONS

SAFETY FUNCTIONS	PREVENTION
Fire (living areas and industries)	Thermocouples and smoke stacks are present in segments. Industrial vessel is depressurized.
Electrical fires	Usage of spark free devices and finer polymer cables. Circuitry components are subcontracted to **Electro Protect.**
Solar Flares/Rad-iation	Polyethylene and Thermal Buckystructures used.
AI Malfuncti-on	The AI will be rebooted and software updated . Regular maintenance checks are also conducted.
Depressurization	Barometers are throughout the settlement . Depressurized area sealed. Pinhole breaches repaired by the Excon.
Solar Panel Degradation	Solar panels are **subcontracted** to **Zap! Industries**
Medical emergency	LinkEd is used to help detect medical emergency and automatically call the ambulance
Disease outbreak	The affected people will be quarantined and treated . The settlement will be decontaminated .
Dust mitigation	Dust sensors equipped throughout the settlement. Electrode based air filtration system used .

5.2.2 EXTERNAL MAINTENANCE AND REPAIR

The **Excon** will be **repurposed** for external repair and maintenance, hence saving time and resources. This is done by upgrading its software for maintenance and repair.

Software:- Eagle , HavOk

Data storage:-15 petabytes

5.2.3 INTERNAL MAINTENANCE AND REPAIR

The **Incon** will be **repurposed** for internal repair by upgrading its software for the same. It consists a large variety of tools for interior construction and finishing which can be interchanged and are stored in Incon's storage compartment ,such as a cutter, welder, adhesive injector , solder capable arms tip

Software:- HavOk, Eagle

Data storage:-10 petabytes

5.2.4 HUMAN INTERVENTION :

A team of authorized personnel named "**Operators**" governs all operations and monitors all functions throughout the settlement. They are responsible for the smooth functioning of all activities on Benevectoras and directly over see robotic activities, day to day operations, communication and data flow . In cases of emergency a fast response team is formed, consisting of 12 Operators .

Software :-ControlOS (used by the Operators to monitor operations and activities)

5.2.5 CONTROL ROOM :

Control rooms consist of a team of authorized personnel, called the Operators who monitor data flow from Earth to Benevectoras and vice-versa. They have access to all critical data and live feed throughout the settlement. The control room provides the Operators with the infrastructural computing capabilities to effectively carry out monitoring and control of activities on the settlement .

5.2.6 DATA SECURITY IN CONTROL ROOM

Individual; workstations are protected via a combination of biometric locks that is encrypted via 2048-Bit Homomorphic encryption.

Networking and servers of the control room are secured via quantum encryption .

5.2.7 SURVEILLANCE SYSTEMS:

- **<u>Homes</u>-** Homes will be equipped with High Definition cameras with a field of view of 180° which uses long exposure sensors to establish clear monitoring in low light. They also have features like motion detection which works in alliance with HomeConnect (refer 5.3). For the owners' privacy, only the owner has authorisation to access these cameras.
- **<u>Industries</u>-** The HD 180° FOV cameras are paired with various other sensors like the thermal detectors and smoke detectors. These can be further customised as per the industry's needs.
- **<u>Exterior-</u>** The exterior surveillance modules are equipped with cameras, thermal Imaging and microwave sensors that will be used to detect anomalies such as unusual temperatures cracks and breaches in the hull of the settlement.

5.2.8 LEVELS OF SECURITY

Levels of Access	Security system	Usage Location
Level-1 (Gamma)	Fingerprints scanners	Residences and offices offices
Level-2 (Beta)	Vein mapping and palm geometry	Industrial area
Level-3 (Alpha)	DNA mapping and facial vein vein mapping	control

Table 5.3 *security clearance*

Figure 5.6: *Control room*

5.3 HABITBILITY AND COMMUNITY AUTOMATION

5.3.1 DEVICES TO ENHANCE LIVABILITY IN THE COMMUNITY

1. **MedBay -** It is a tele-operated bot which performs organ printing and organ transplant on its own. It has multiple orthographic cameras that enables MedBay to operate in case any specialist(doctor) is not available.

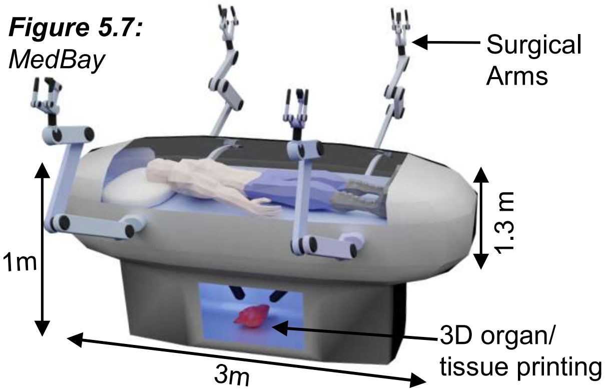


Figure 5.7: *MedBay*

2. **LinkEd**-It is a wearable communication device worn by all settlers. LinkEd contains various sensors like the Heart Rate monitor, Oximetry Sensor, Skin Conductance sensors and Thermometers.It can detect if there is a medical emergency and automatically calls for assistance . The LinkEd also has a high-resolution camera that enables a Machine Learning pipeline consisting of a real-time deep neural network model that computes a 3D mesh model of any object which is then displayed by a holographic **Multimodal Acoustic Trap Display** on each LinkEd band

Figure 5.8: *LinkEd*

5.3.2 DEVICES TO ENHANCE WORK PRODUCTIVITY

1. **WorkAI** It is an AI that can be programmed by the user to do monotonous tasks such as transferring data, replying to mails and other tedious tasks.
2. **FlyDesk-** It is based on the Desktop-Based-Persistent-VDI(Virtual Desktop Interface) framework, FlyDesk is a centralized mainframe server that delocalizes processing to make it faster. This also

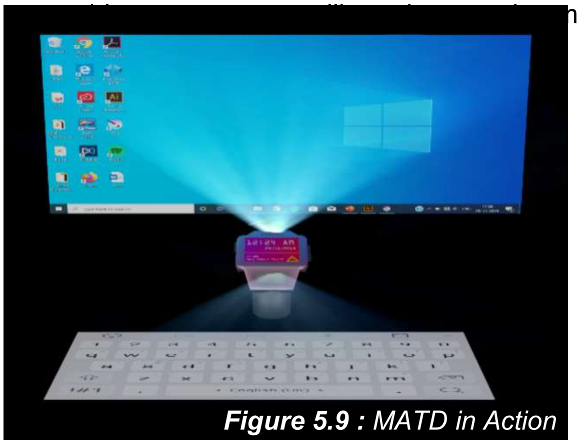


Figure 5.9 : *MATD in Action*

3. Janitorial and cleaning bots used in work environments has been **subcontracted to Bots4u .**

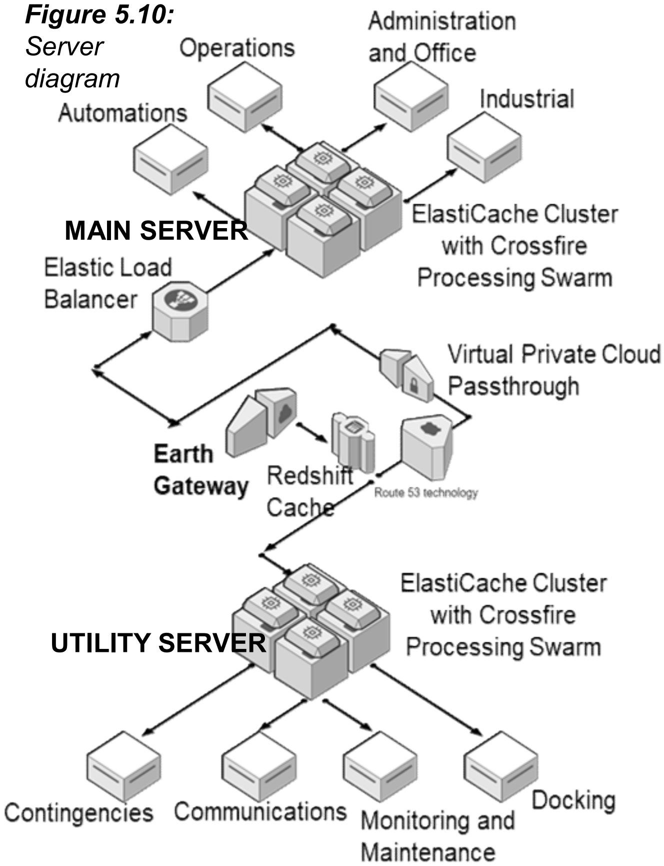
5.3.3 DEVICES TO ENHANCE HOME CONVENIENCE

1. **HomeConnect-** All devices in homes will be interconnected. The user could set up their routine accordingly and personalize their routine with the help of an AI which tracks their day-to-day activities and automates processes like making breakfast, adjusting the thermostat, managing lights, locking the doors, etc. It autonomously orders supplies/ commodities based on the amount used. Using the cameras, motion sensors and LinkEd, HomeConnect detects if the user is having a seizure, stroke or has been injured physically and is unable to contact emergency services.It automatically calls for the ambulance, further ensuring the safety of the settler.
2. Bots for housekeeping, household requirements and personal automation are **subcontracted to Bots4u.**

5.3.4 PERSONAL PRIVACY

All Control room workstations will be protected by **biometric locks(Iris)** and encrypted via 2048-BIT Homomorphic Encryption and all personal devices will be protected by 256-BIT AES(Advanced Encryption Standard).

Figure 5.10: *Server diagram*



Server	Storage (PB)	Processing (Ghz)
Main Server		
Automation	300 PB	140 Ghz
Operations	300 PB	120 Ghz
Admin. & Office	200 PB	90 Ghz
Industrial	200 PB	80 Ghz
Utility Server		
Contingen-cies	400 PB	125 Ghz
Communic ations	300 PB	140 Ghz
Monitoring & maintenan ce	400 PB	130 Ghz
Docking	350 PB	120 Ghz

Table 5.4 *Stipulations*

5.3.5 SERVER DIAGRAM

- Our servers are divided into 2 types, the **main servers** and the **utility servers**. The Earth gateway node is protected via a VPC(Virtual Private Cloud).
- To make the data processing faster, the network is equipped with a **redshift cache** that makes the process faster. The server connections are equipped with **advanced Route53 technology** that makes the connection more responsive.
- For balancing of load, an elastic load balancer is placed on servers with excessive load. The servers are equipped with **ElastiCache** servers accompanied by a **CrossFire processing swarm.** ElastiCache servers have variable processing powers which are allocated based on the amount of load.

5.4 AUTOMATION AND DOCKING

5.4.1 TUG FLEET CONTROL CENTER

The transport control room is located on the spokes between the industrial vessel and the segmented sections. The transport control room seats 10 crew personnel at all times ensuring safety and supervision of the space tugs. As rings are added after IOC the tug control centers are added in the spokes of the new rings ,increasing capacity.

5.4.2 TUG REPAIR BOT

The tug repair bot is located in a hatch adjoining the dock for the tug . It is a retractable bot which inspects the tug and performs the necessary repair for maintenance of the tug.It has smaller arms that extend out conducting detailed repair.

Software : Eagle

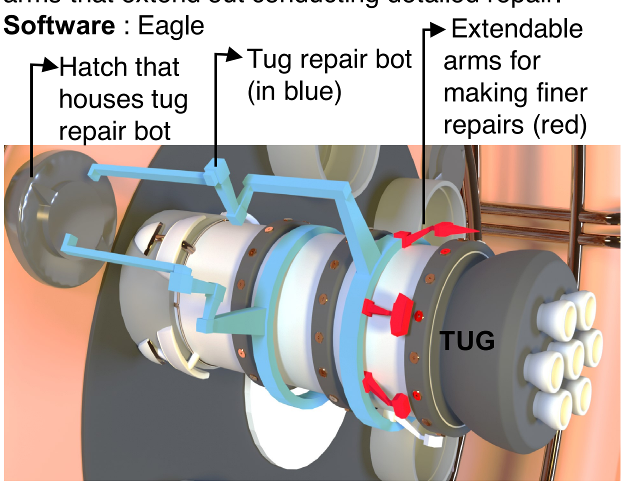


Figure 5.13: *Tug repair bot*

5.4.3 LOADING AND UNLOADING OF CASSSCs IN TUG PORT

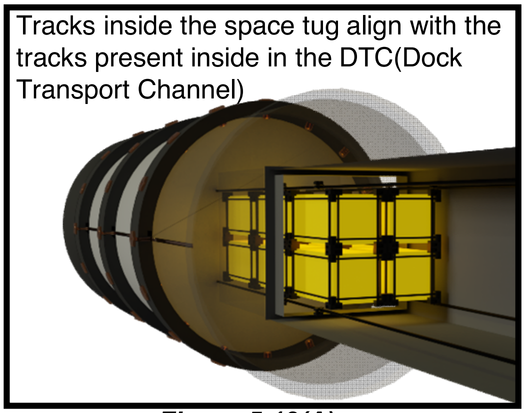


Figure 5.12(A)

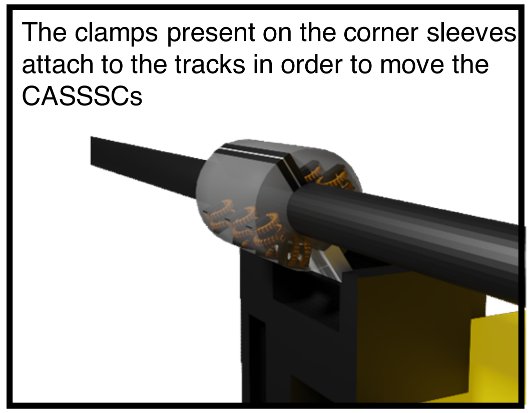


Figure 5.12(B)

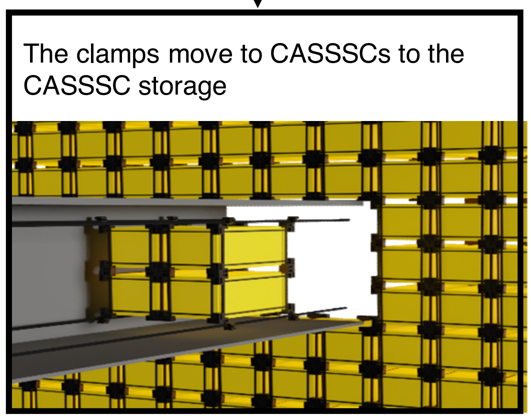


Figure 5.12(C)

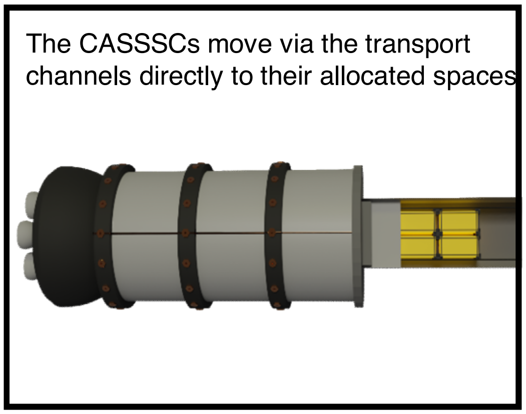


Figure 5.12(D)

- The space tug will dock onto the tug port, perpendicularly to the tug port, with the hemispherical clamps locking onto the tug port. The CASSSCs are then directly fed into the 3D track system which will then transport the CASSSCS from the space tug bay to the required area.
- The CASSSCs are transported from the space tug into the settlement by moving the CASSSCs via the DTC directly into the settlement (see fig. *5.12(A)*)

5.5 AUTOMATION IN MANUFACTURE AND TRANSPORT OF COMMODITY OF MARS

5.5.1 3D TRACK SYSTEM

The Corner Sleeves of the CASSSCs move on tracks specifically designed to allow omnidirectional movement. The corner sleeves have retractable clamps(in blue) that attach to the tracks. The placement of these clamps ensure that CASSSCs have ample support; at any given instant, at least 8 pairs of clamps hold a CASSSC in its place. They lead the CASSSCs directly from storage to the main transport channel. The main transport channel carries these CASSSCs to docks, industries and to one side of the rotational interface.

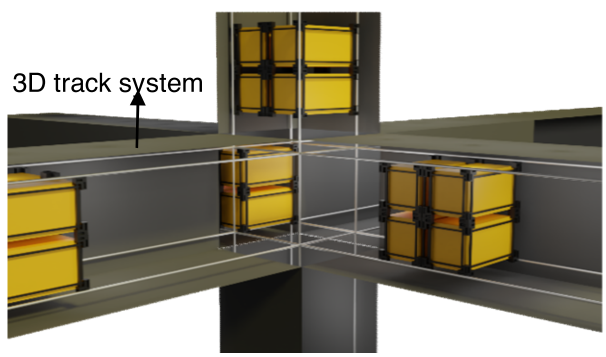
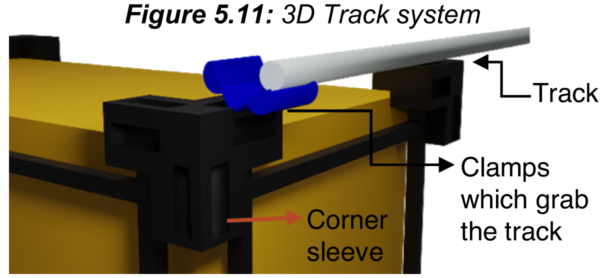


Figure 5.11: *3D Track system*



5.5.2 MANUFACTURING OF MARTIAN COMMODITIES

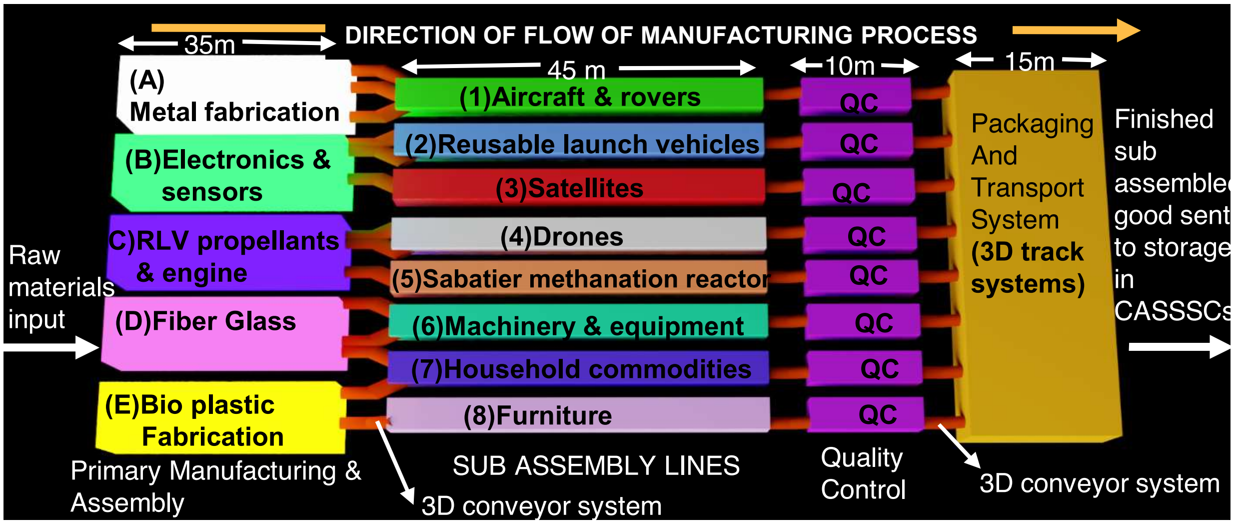


Figure 5.14: Industrial area layout

5.5.1 Automation in manufacture

- Manufacturing of commodities is done in the industrial vessel using a **multi-stage manufacturing and assembly process**, carried out in the industrial vessel.
- The commodities required for Mars settlers are being manufactured in **the primary manufacturing sector& secondary manufacturing sector** which provide the required commodities for use on Mars in their respective **sub-assembly** for Mar settlers .
- **Food Processing** takes place in the **spokes** , using a no. of automated systems in sync we are able to efficiently process harvested crop into wheat, rice, pulses and oats which is then packaged .

PRIMARY MANUFACTURING SECTOR

A) Metal fabrication :

The primary metal fabrication industry consists of robot and machinery involved in cutting, drilling, welding, hemming and flattening of metal sheets according to requirements. Capable of processing a large variety of metals and alloys .

Raw material – Various metals and alloys.

B) Electronics and Sensors :

Responsible for manufacture of the electronics ,sensors ,chipsets and other required electrical devices.

Raw material - Silicon, metals **.**

C) RLV propellants & engine :

The engines for use in RLVs(Reusable Launch Vehicle) is sub assembled here.And propellants are filled in tanks.

Raw material – propellants,metal sheets,sensors

D) Fiber glass :

The fiberglass industry provides for raw material for various assembly lines and is used by Mars settlers for building greenhouses.

Raw material Silicon dioxide

E) Bio plastic fabrication :

The plastic industry uses injection molding technology to produce plastic commodities . The 3D plastic mold is rotated at high speeds to ensure that the plastic evenly distributes.

Raw material : Bio plastic plant grown with aeroponics

SECONDARY MANUFACTURING SECTOR (Sub assembly lines)

This sector consists a no. of assembly bays which complete **the sub-assembled** product which is ready to be shipped to Mars. Comprises of 8 assembly lines :

(1) **Aircraft & rovers-** ensures a quality and safe craft after many levels of quality
(2) **Reusable launch vehicles-** Only provides sub assembly of RLV which can be easily assembled on Mars
(3) **Satellites-** Capable of constructing a variety of reliable satellites for different uses.
(4) **Drones-** High efficiency drones of varied purposes capable of functioning in the thin of atmosphere of Mars .
(5) **Sabatier methanation reactor –** Provides infrastructure to produce water and methane
(6) **Household commodities** – Provide for basic household commodities
(7) **Machinery and equipment** – High quality machinery tools and equipment produced
(8) **Furniture –** Made from sustainable bio plastic

QUALITY CONTROL SECTOR

It thoroughly tests each and every product produced achieving the highest standards of quality , ensuring a quality product.

TRANSPORTATION

We are using a 3D conveyor system which can direct objects even in zero gravity for transporting of goods between sectors in the industry.(see table 5.5)

We use the 3D track system for transport of CASSSCs inside the industrial vessel .(tug port, storage , industries). All commodities produced will be transported in CASSSCs .

5.5.1 LIST OF AUTOMATION SYSTEMS EMPLOYED IN MANUFACTURING AREA

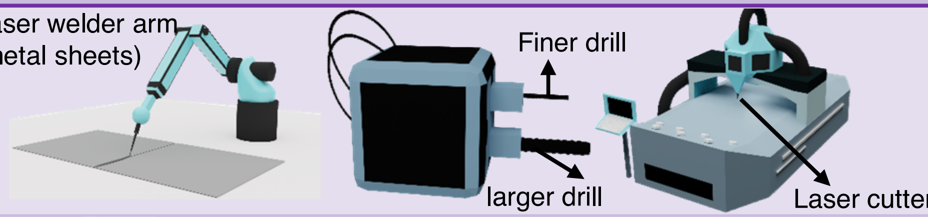
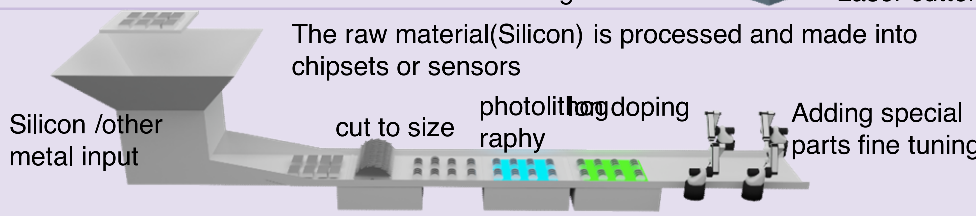
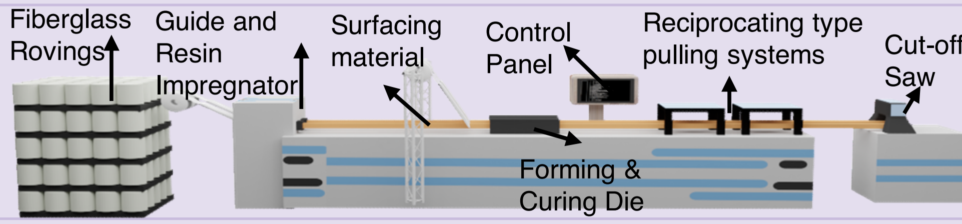
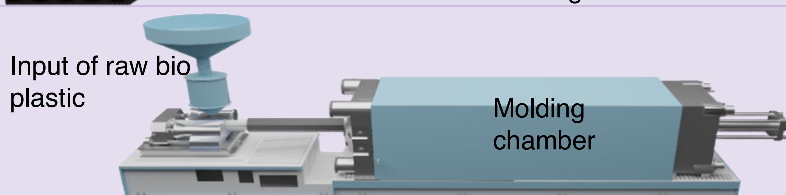
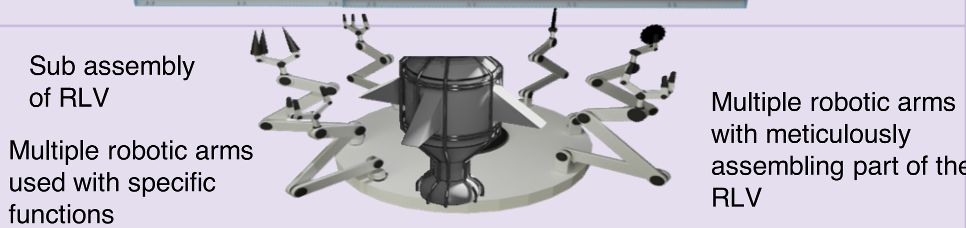
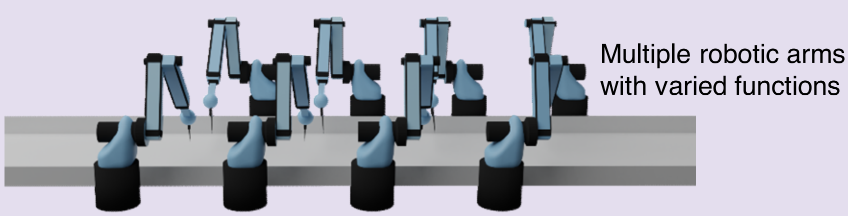
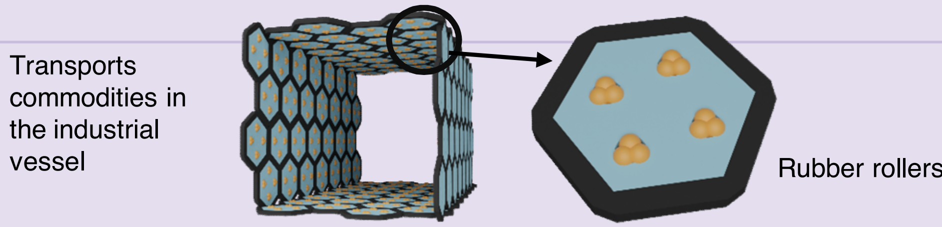
TYPE	SYSTEM INVOLVEVED	QTY (IOC, incr-eme-nt)
METAL FABRICATION (primary)		20,10
Electrical and electronics (primary)		10,10
Fiber glass (primary)		20,10
Bio plastic fabrication (primary)		40,20
Rocket assembly (primary)		10,20
Assembly lines (secondary)		80,20
3D conveyor system (transport)		640, 280

Table 5.5: *List of automation systems used for manufacture*

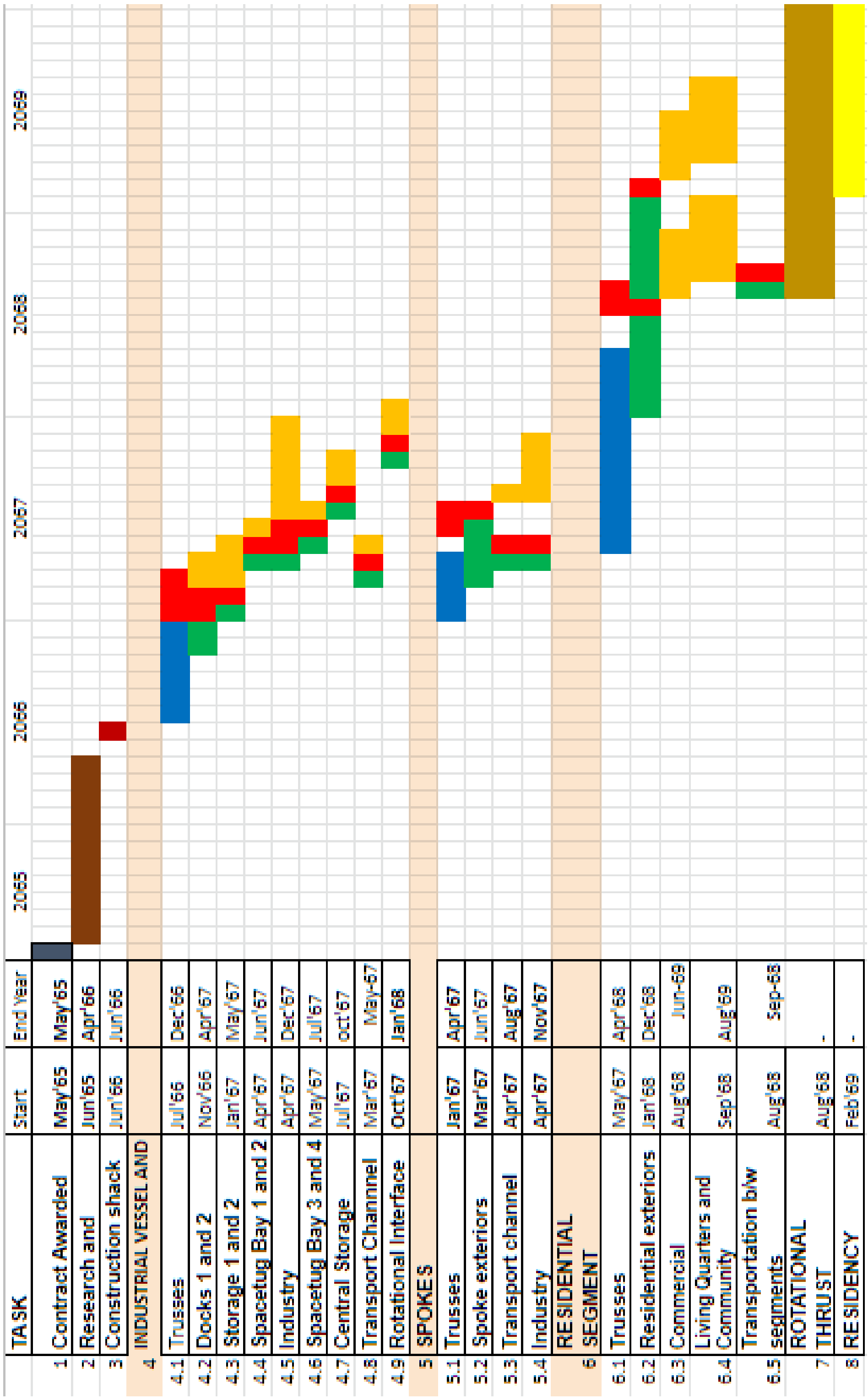
6

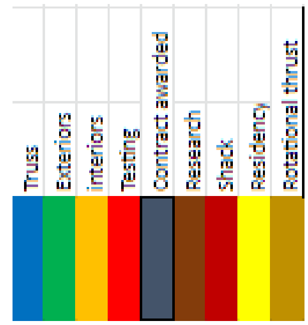
COST AND SCHEDULING

"Cost is more important than quality but quality is the best way to reduce cost"

NORTH DONNING HEEDWELL

COST AND SCHEDULE



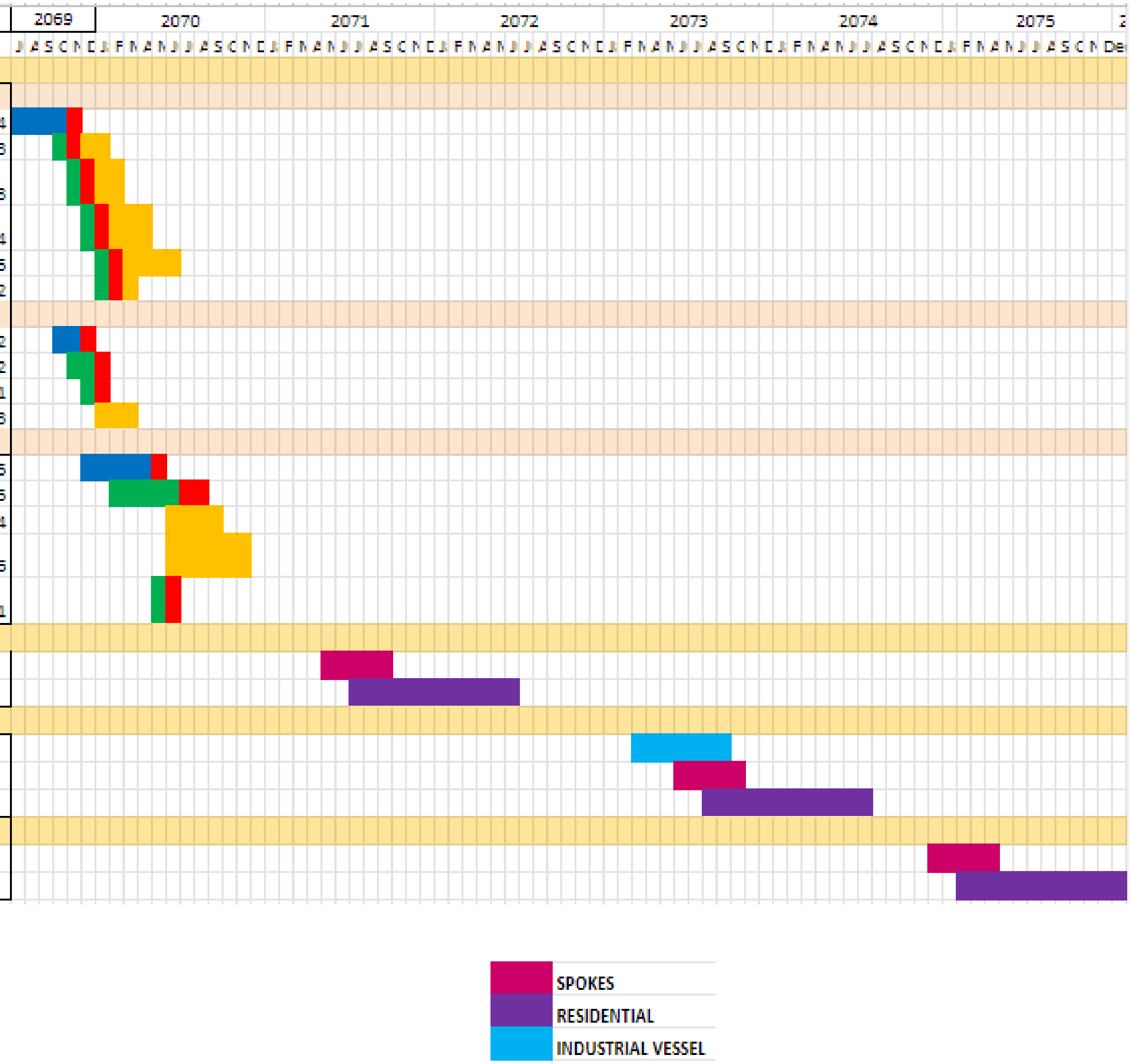


6.1 DESIGN AND CONSTRUCTION SCHEDULE

Taking into account the magnitude of investment that would go into making Benevectoras, the time span is a key element that dictates bringing Benevectoras to life in a realistic and profitable manner.

Many processes are carried out simultaneously for optimisation.

	Phases	START	END	Month
1	PHASE 1			
1	Industrial Vessel	Jul-69	Jan-71	
1.1	Trusses	Jul-69	Oct-69	4
1.2	Dock	Oct-69	Jan-70	3
1.3	Storage 1 and Spacetug Bay 1	Nov-69	Feb-70	3
1.4	Storage 2 and Spacetug Bay 2	Dec-69	Apr-70	4
1.5	Industry	Jan-70	Jun-70	5
1.6	Spacetug 3	Jan-70	Mar-70	2
2	2 Spokes	Oct-69	Mar-70	
2.1	Trusses	Oct-69	Nov-69	2
2.2	Spoke exteriors	Nov-69	Dec-69	2
2.2	Transport channel	Dec-69	Dec-69	1
2.4	Industry	Jan-70	Mar-70	3
3	Residential Segment	Dec-69	Nov-70	
3.1	Trusses	Dec-69	Apr-70	5
3.2	Residential exteriors	Feb-70	Jun-70	5
3.3	Commercial	Jun-70	Sep-70	4
3.4	Living Quarters and Community	Jun-70	Nov-70	6
3.5	Transportation b/w segments	May-70	May-70	1
2	PHASE 2			
1	2 Spokes	May-71	Sep-71	
2	Residential Segment	Jul-71	Jun-72	
	PHASE 3			
1	Industrial Vessel	Mar-73	Sep-73	
2	2 Spokes	Jun-73	Oct-73	
3	Residential Segment	Aug-73	Jul-74	
	PHASE 4			
1	Spokes	Dec-74	Apr-75	
2	Residential Segment	Feb-75	Jan-76	



6.2 COSTS

In order to enable swift construction processes, a large number of construction bots and human resources have been employed.

STRUCTURAL COSTS					
Material/ Sub-Assembly	Res. Rings (kg)	Spokes (kg)	Industrial Vessel (kg)	Total Mass (kg)	Total Cost
Truss (min)	6,664,590	1,715,205	3,001,408	11,381,203	$317,467,270
Lunar Concrete	1,216,614,338	313,108,937	547,904,133	2,077,627,408	$29,917,834,668
Al Foam	154,803,444	39,840,351	69,715,968	264,359,763	$1,691,902,481
Al	503,965,627	129,701,037	226,961,693	860,628,357	$6,540,775,515
Polyethylene	36,589,905	9,416,810	16,478,320	62,485,035	$309,925,773
Windows	912,737,188	-	-	912,737,188	$14,603,795,006
Structural Cost at Final Operational Capability (FOC)					**$53,381,700,713**

TRANSPORTATION COSTS		
Commodity	Units	Total Costs
Furniture	19,958,066	$10,268,424,751
Fiberglass	67,376	$34,664,895
Clothes	85,738	$44,112,407
Household commodities	52,804,078	$27,167,698,248
Machinery Sub Assemblies	1,858,824	$956,364,948
Styrene	41,549	$21,376,708
Industries Raw Materials	9,671,876	$4,976,180,047
Miscellaneous	-	$1,000,000,000
Cost at FOC		**$44,468,822,005**

AUTOMATIONS COSTS		
Bots	Units	Total Costs
InCon	504	$705,600,000
ExCon	372	$651,000,000
EVA Module	36	$14,400,000
Loading Unloading	48	$1,728,000
Agrobot	84	$987,000
LinkEd	83	$12,450
Delivkart	8,800	$1,529,000,000
Internal Repair	168	$1,965,600
MedBay	36	$12,129,300
Shuttle	24	$675,948
Industrial Robot	36	$127,980,000
Cost at FOC		**$3,045,478,298**

HUMAN RESOURCES		
Jobs	People	Total Costs
Research and development	1,752	$1,542,865,875
Tug Course supervising	4	$2,661,435
Industry and structure Inspecting	6	$4,080,867
Testing	154	$93,113,319
Cost at FOC		**$1,642,721,496**

SUBCONTRACTOR COSTS		
Subcontractors	Units	Total Costs
3D Logistics	135,845	$4,406,137,343
Blown Away	706,710	$554,060,789
Bots4U	135,845	$7,543,752,703
Bottom Cleaners	2,934	$68,494,230
BuckyBreakthr-oughs	1,007,442,439	$7,253,585,,556
Clean up Your Act	2,934	$198,138,888
EST	3,800	$1,520,000,000
Holey Moley	4,117	$405,374,268
Lossless Airlocks	134	$4,335,677,200
Large Print	84	$24,276,000
Orbit Link Communications	4	$5,280,000
RLP	11,836	$3,550,800
Stuff of Life	49,247,484	$1,154,853,500
Toss it To me	1,391,804	$473,213,360
Waste Products	644,406	$219,098,040
ZAP! Industries	218,132,125	$5,398,770,101
Cost at FOC		**$33,564,262,788**

SPACE TUGS		
Type of Tug	Units	Costs
Propulsion tug	96	$2,329,639,092
Cargo tug	18	$1,832,367,799
Passenger tug	4	$3,681,299,363
Cost at FOC		**$7,843,306,254**

TOTAL YEARLY COSTS			
Year	Cost	Year	Cost
2065	$261,689,419	**2071**	$486,315,069
2066	$42,425,313,985	**2072**	$2,244,440,641
2067	$40,103,511,766	**2073**	$486,315,069
2068	$35,102,415,393	**2074**	$2,244,440,641
2069	$15,616,653,219	**2075**	$486,315,069
2070	$2,244,440,641	**2076**	$2,244,440,641
Total Cost			***$143,946,291,554***

7
BUSINESS DEVELOPMENT

"Profit is the ignition system of our economic engine"

NORTH DONNING HEEDWELL

BUSINESS DEVELOPMENT

Northdonning Heedwell understands that your objective for ideating Benevectoras is for it to serve as **a transport vessel** for cargo and in-transit population between Earth and Mars that can also provide **assets mandatory for colonization** and careful **exploitation of Mars' resources**. Moreover, we perceive your business ventures to be the barter of resources between Earth and Mars, self-sufficiency of the colonizing population and expanding the colony control for economic purposes in the most fluent way possible. Hence, keeping your goal in mind we have devised an **intricate, competent and coherent system** upon careful evaluation of your requirements and your notion of what defines Benevectoras.

7. 1.PORTS FOR SPACETUGS

The port on Benevectoras takes utmost care of safe exchange of cargo and people while also emphasizing on the efficiency.

7.1.1 SPACETUGS AND DOCKING

The task for manoeuvring Benevectoras into Aldrin Cycler orbit and providing necessary course corrections is undertaken by **Propulsion Spacetugs. (**functioning explained in 3.4 and Appendix A). They possess the capability to detach but **stay attached to the pushing interface** at all times, possess a powerful engine and are repaired externally itself. Such powerful engine requires constant fuelling provided by the fuel storage placed directly below the pushing interface.

The docks for Cargo and Passenger Spacetugs are placed on either ends of the Industrial Vessel that is both loading and unloading station for spacetugs. There are 7 docks on either side (explained in 2.4). The second group of docks are at the pushing interface (as shown in figure 7.1) for the permanent attachment of Propulsion docks. The spacetugs are repaired externally by Repair Bot.

7.1.2. RAPID LOADING AND UNLOADING

The net transfer of all the cargo and passengers is done in the time window of **eight days**. The numerous docks located on both the faces of Industrial Vessel ensure multiple incomings of space tugs at once.(refer to 2.1.4).

Since the Cargo Spacetug do not require sealing and pressurization like the Passenger Spacetug (*Soft Capture System, IDSS),* the unloading time is reduced(refer to Appendix A). The Tug Port and the Industrial Vessel, being of the same radius allows straight channels connecting each docks directly to the storage area attached to the tug port.(refer to point 5.4). The **multi-channel** docking system ensures rapid and fluid movement of CASSSCs that are fed directly to storage.

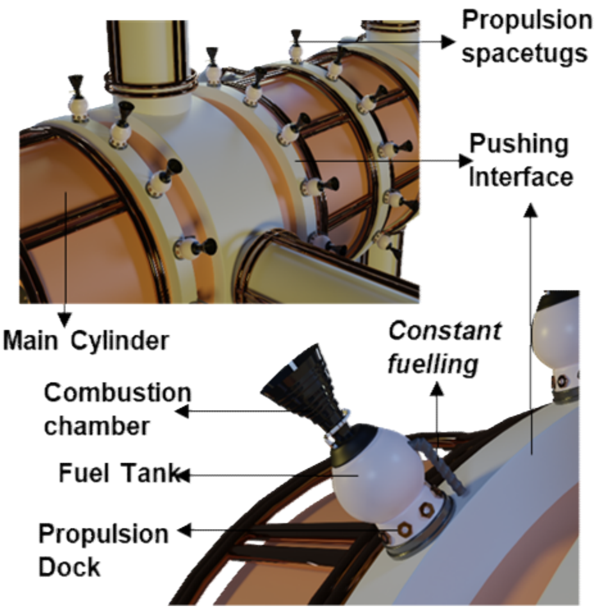


Fig.7.1: *Propulsion Spacetugs Doing Course Corrections*

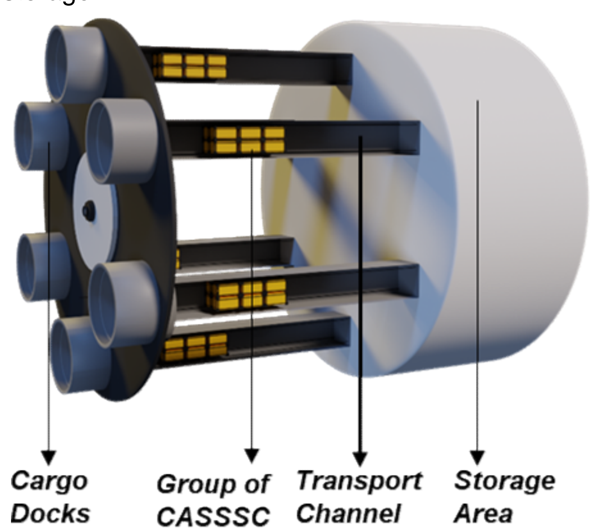


Fig.7.2: *Docks*

7.1.3 SAFE TRANSFER BETWEEN ARTIFICIAL GRAVITY AND 0g

Keeping safety in mind, Benevectoras has designed the **Spoke Elevator** for the convenient transfer of people and cargo between 0g and artificial g environment. The Passenger Lift is pressurized for sustenance of passengers and consists of **17 seats** with a coherent buckling system. A pressurized room is placed attached to the surface of the Industrial Vessel, connected to the elevator where the passengers wear and remove their space suits.
After wearing the space suits, the passengers enter the free-manoeuvrable vehicle between the rotating and non-rotating interface (refer 2.1.7)

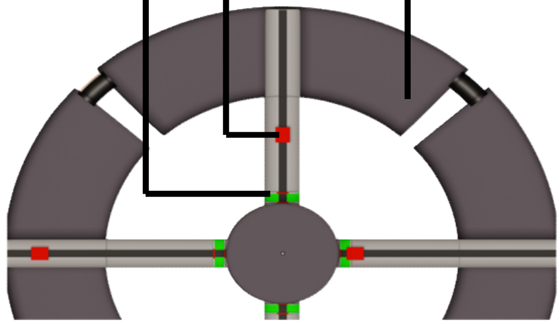


Fig.7.3: *Spoke Elevator*

7.2.MANUFACTURING COMMODITIES FOR MARS USE

Benevectoras is a self-sustaining ecosystem that not only fulfils the essential demands of its passengers but also caters to every request of theirs with a proficient and dynamic system.

7.2.1.EXCESS CAPACITY

Benevectoras' business pursuits ensure future expansion. Increasing capability means proficient use of expanded plant area and space, bots and machinery increment and surplus quantity.
The volume for manufacturing furniture and machinery and the toiletries are **increases twice (**at 1st and 3rd Earth pass) and food processing unit **increases 5 time(**at every Earth Pass) with addition of spokes.

Type of Bot	Total no. of bots
Primary Manufacturing bot	70
Secondary Manufacturing bot	20
Agro bot	14

Table 7.1: *Increment in Automation System*

The above mentioned increment in number of bots takes place at every Earth pass and are used in the industries for Furniture and machinery, Kitchenware, Toiletries, Food processing and Agricultural Vertical stacks to meet the increasing demand at high pace.

The surplus quantities are provided to in-transit Mars settlers are every Mars pass is explained in table 4.10.

7.2.2 LOADING AND UNLOADING AGRICULTURAL AND HOUSEHOLD COMMODITIES IN CASSSCs

Agricultural produce is taken from the Vertical stacks to the Food processing Industry. Once the food is processed, it is securely wrapped and packed with the help

Table 7.2 *Excess Area Capacity*

Capacity	Location	Area increase (m^2)	Volume increase (m^3)
Furniture and machinery	Industrial Vessel	1378.858	27577.56
Toiletries	Industrial Vessel	2048.857	20488.57
Food processing	Spokes	1792.750	-
Agro- Vertical stacks	Residential Segment	41684 m²	-

of **thermoforming and vacuum sealing that** increases the shelf life by up to six times, ensuring a fresh bite.

Similarly, The household commodities consist of fragile items that are packed into layers of protective material. For safe loading and unloading of cargo from CASSSCs, **dual-jawed retractable arms** are provided to place and take out materials with utmost precision and care. CASSSCs are shipped to the storage area next to the docks to be loaded into the outgoing cargo spacetugs.

Fig.7.4: *Retractable Arms Putting commodities into the CASSSCs*

7. 3 INFRASTRUCTURE FOR MARS AND TRADE WITH EARTH

We aspire to provide the Mars settlers with advanced and high quality material that promises profits and rapid economic growth that makes progress synonymous to Benevectoras.

7.3.1 INFRASTRUCTURE FOR MARS

As mentioned in 3.5, Benevectoras manufactures components for various goods as sub-assemblies to assist transport in CASSSCs to and from Mars.

1. Sabatier Methanation Process

Mars air composition has about 95% CO_2 which is resourceful to generate electricity by using the Sabatier Methanation Reaction. Benevectoras is capable of providing fiberglass tubes, Sensors, components for condensers and recirculation pump as sub-assemblies and transport to Mars.

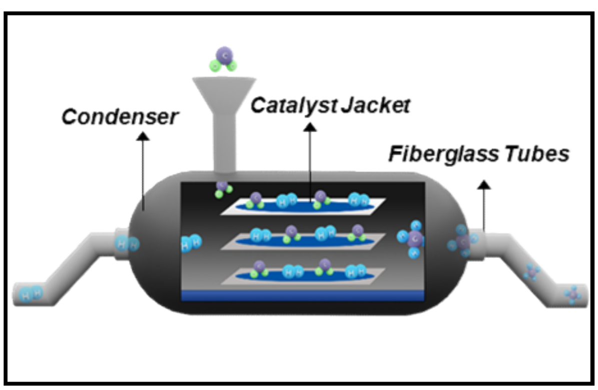


Fig.7.5: *Components of Sabatier Methanation Reactors*

2. Aircrafts, Rovers and Drones

Benevectoras has the dynamic capability to provide aircraft, rovers and drone components. Drones aid in easier access to analyze rough terrains. Aircrafts and rovers aid in transportation and research. Components are manufactured in the Aircraft and Rovers industry.

3. Greenhouse

Importing all the agro-based commodities will not be a viable option to the Mars settlers considering the transportation costs. Benevectoras helps them take a step to self-sufficiency by providing **a safe growing agronomic environment in the shape of greenhouse**. Greenhouse Panels are shaped in the Greenhouse sector and the fiberglass industry and components are manufactured en-route

4.Satellites

Benevectoras is capable of providing common components for satellites as well as expert quality components specific to **Communication, Weather and GPS Satellites** (as mentioned in 3.5). The electronic chips used are manufactured in the Silicon Industry. Satellites not only assist in observations at a larger scale, they also assist in long distance communication. Satellite components can also be manufactures for cis lunar use.

5. Reusable launch vehicles

It is a space launch system that includes the recovery of some or all of the component stages. It will use **scramjet engine** (hence 80% lighter). It will allow a **low cost, is reliable and provide on demand space access**.

No	MATERIALS USED	SOURCE
1.	Metal sheets and alloys	Alexandriat, Bellevistat
2.	Silicon	Silicon Industry
3.	Silicon dioxide	Mars
4.	Titanium dioxide	Mars
5.	Electronic chips	Silicon Industry
6.	Bio Plastic and recyclable plastic	Benevectoras+ Earth

Table 7.3: *Materials used in the manufacturing infrastructure*

7.3.2 TRADE FROM MARS TO EARTH

The Mars' surface is a reservoir of minerals that when treated meticulously can be a source of quality material for cis-lunar use, and Benevectoras is an excellent source to judiciously extract output and price them competitively for cis- lunar use. From the rich variety of minerals, silicon dioxide and titanium dioxide turned out to be the most widely used and most profitably.

1.Silicon Dioxide (*SiO_2*)

It is received as a non-concentrated ore and is purified in the ore concentration industry. It happens to be a major component of glass Hence, is used for the production of aerosol styrene-coated fiberglass. Else, it ca be sent to the Silicon industry for production of silicon and further, of goods.

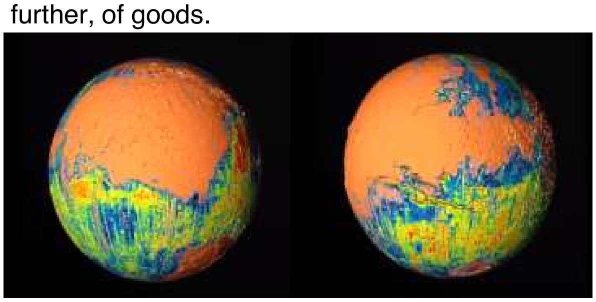


Fig.7.6: *Deposits of a mix of SiO_2 and TiO_2*

2. Titanium Dioxide(TiO_2)

It is purified in the ore concentration industry and in later stages, it is used for the production of various components in aircrafts and rovers, drones, satellites etc.

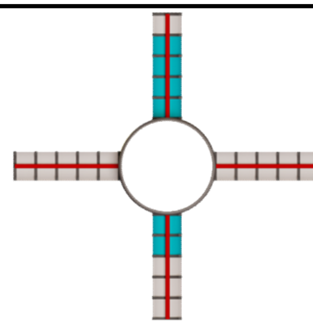
CAPABILITY TO REFINE ORES

The capability for ore refining is provided at the Spokes. Once the ores are refined, for processing it is sent to various industries. The silicon industry further purifies silicon to a usable form for infrastructure development. A purer form of silicon dioxide is used in a huge quantity for the production of fibreglass. Similarly titanium dioxide after concentration is used as a raw material for satellites, aircrafts, rovers etc. Benevectoras ensures a meticulous use of the available resources and making multi-purpose products for Earth and Mars. All these raw materials such as refined silicon, titanium dioxide etc. as well as components made from these such as aircrafts, rovers, satellites etc. can be provided for cis-lunar use.

7.3.3 TANK CAPACITY FOR DEUTERIUM

Deuterium being relatively abundant on Mars attracts attention and is the futuristic fuel for fusion ships when combined with lunar-3 Helium. Benevectoras being the multi-purpose transport vessel provides storage tank capacity for deuterium in the spokes as shown in the figure below. A net volume of 154,773m^3 is given at IOC i.e 6 floors. At each Earth Pass, 2 floors i.e a tank capacity of 51,591m^3 volume is added. The tanks provided are made with fiberglass and is further sealed into isolation.

Figure 7.7: *Deuterium Storage in Ring 1*



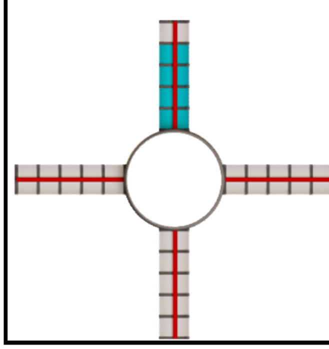


Figure 7.8: *Deuterium Storage in subsequent rings*

8

APPENDIX A:

OPERATIONAL SCENARIO

NORTH DONNING
HEEDWELL

OPERATIONAL SCENARIO

A.1 TRADE STUDY

In order to determine number of tugs required and simultaneously showcase the efficiency of our novel space tug designs(refer to 3.4), a trade study including qualitative and quantitative analysis has been carried out and results have been visualized to clearly establish Benevectoras' Space tugs a league apart from standard models.

Analytic Hierarchy Process(AHP):

Factors:

- Material Cost
- Manufacturing Cost
- Repairability
- Durability
- Carrying Capacity
- Production Time
- Fuel per Tug

Scoring Criteria:

A. 1 means criteria A and B are equally important
B. 3 means A is moderately more important than B
C. 5 means A is strongly more important than B
D. 7 means A is thought to be much more important than B
E. 9 means A has been demonstrated to be much more important than B.

Pair-Wise Decision Criteria Comparison:

Criteria	Mat Cost	Mfg cost	Repairability	Durability	Carrying Capacity	Time to produce	Fuel per tug
Mat Cost	1.00	0.33	0.20	0.33	0.11	0.14	9
Mfg Cost	3.00	1.00	0.20	5.00	0.14	0.33	0.2
Repairability	5.00	5.00	1.00	5.00	0.33	3.00	0.33
Durability	3.00	0.20	0.20	1.00	3.00	0.14	5
Carrying Capacity	9.00	7.00	3.00	0.33	1.00	9.00	5
Time to produce	7.00	3.00	0.33	7.00	0.11	1.00	0.14
Fuel per tug	0.11	5	3	0.2	0.2	7	1

Normalized Criteria Matrix:

	Mat Cost	Mfg cost	Repairability	Durability	Carrying Capacity	Time to produce	fuel per tug
Benevectoras	0.4	0.37	0.7	0.8	0.9	0.4	0.55
Boeing	0.6	0.634	0.3	0.2	0.1	0.6	0.45

Comparison has been done with respect to a standard Boeing Space tug in order to highlight achievements.

Criteria Weights/ Preference Vector: (*From Pair-wise decision criteria normalized)

Mat Cost	Mfg Cost	Repairability	Durability	Multi-Purpose	Time to produce	Fuel per tug
0.089357	0.078204332	0.160458	0.073829	0.286561	0.142797	0.168793

Matrix computations:

Final Scores:

⇒ **Normalized Criteria Matrix x (Preference Vector)$_T$ *Matrix Dot product with Transpose of Preference Vector**

Benevectoras Tugs	0.64
Boeing Tugs	0.36

The AHP leads us to conclude Benevectoras space tugs as the optimal transportation thruster of Benevectoras.

Transfer Vehicles:

Requirements and Factors leading to multi vehicle types:

a. Transportation Intra-residential
b. Transportation Intra-Industrial vessel
c. Transportation across the spoke
d. Transportation between Rotational and Non-Rotational Interface

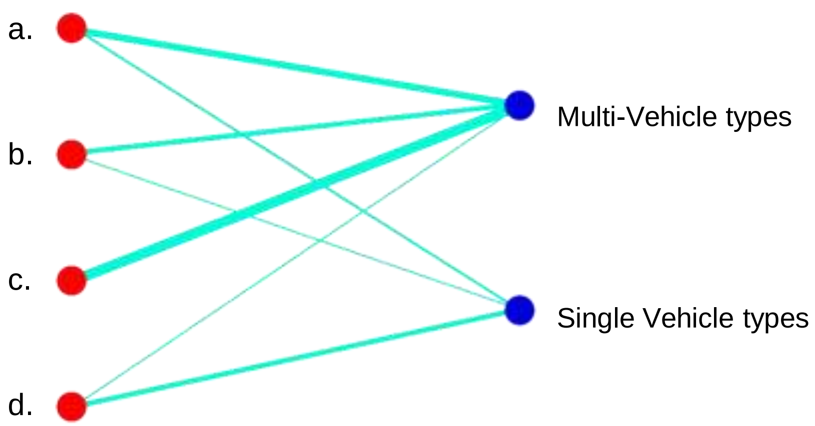


Figure 8.1: *Visualization of Weighted Sum of Factors*

We observe that the Node of Multi-Vehicles has the largest weighted sum**(*The thickness of the line demonstrates the weight vector)** hence Multi-Vehicle System has been employed in our design for Benevectoras.

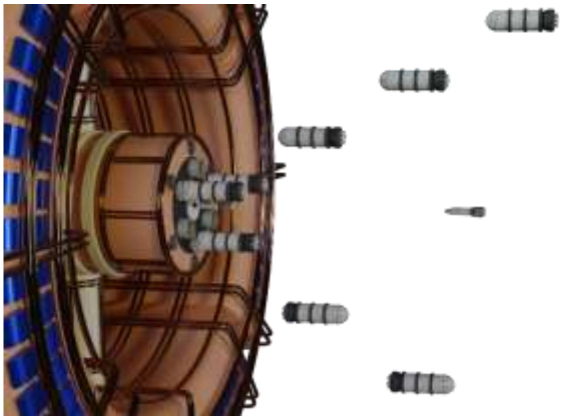


Figure A.2: *Space tugs arriving at, docking and leaving Benevectoras.*

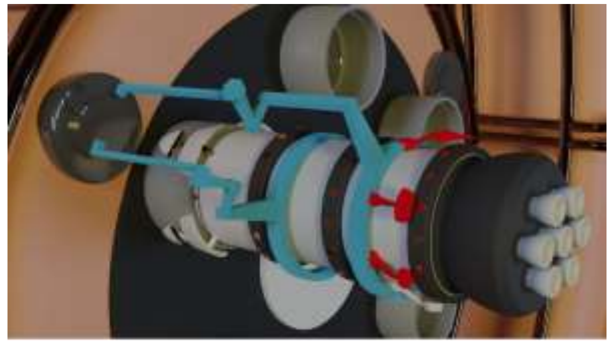


Figure A.3: *Space tugs refuelling and under repair.*

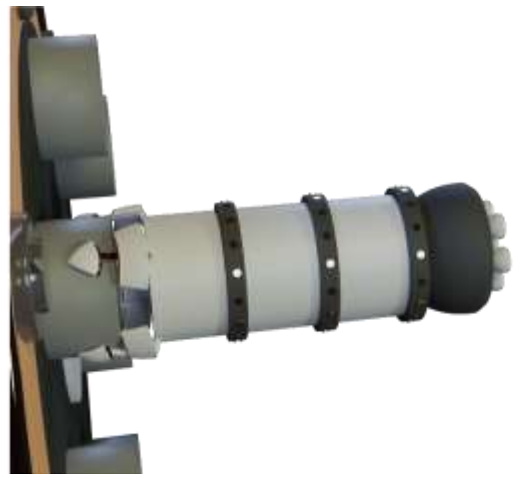
A.2 DETERMINING NUMBER OF TUGS AND DOCKS FOR TRANSFER OF CASSSCs AND PEOPLE

Restriction of movement of cargo and people to eight days at both Earth and Mars necessitates multiple tugs making trips simultaneously. In order to determine the number of tugs and the number of docks required to accomplish this task, an estimate of the time it takes for one trip needs to be made.

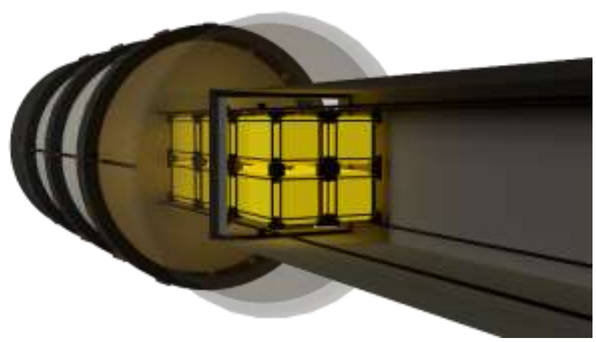
One trip would constitute movement of a tug from low orbit to Benevectoras, docking and transfer time, and from Benevectoras to low orbit again.
Thus, without considering any major advancements in technology allowing for faster travel times, a fairly reasonable estimate for the time taken to complete one trip would be about **3 and a half hours**.

One tug is capable of carrying **12** CASSSCs. From the number of CASSSCs that need to be moved within that **192 hour period**, it is found that **516 trips** are required.

If the tugs are launched at **20 minute intervals**, then 12 cargo tugs can make 516 trips in just a little over 7 days. Increasing the interval by nearly a minute and a half enables the tugs to make the 516 trips in less than eight days, while at any given moment, only 8 docks of the 12 would be occupied. If the tugs face any damages, they may be moved to any of the four vacant docking stations, where tug repair bots situated near the dock can attend to the tug.



The CASSSCs would be encased in the corner sleeves(5.5) before placing them onto the tug. The system of rails inside the tug and that of the dock, when aligned perfectly after the tug is docked allows for rapid transfer of the CASSSCs from the tugs to the CASSSCs storage slices.



Using a similar process, it can be determined that in order to move 1800-6300 people using a space tug carrying 90 people, one trip taking over 6 hours for completion, one dock would more than suffice, while the other can act as a repair station.

A.CONCLUSION:

The trade study helped us conclude that multiple vehicles and our increased carrying capacity system was concretely the right way to go about the problem.

Net results drawn and operations carried out:

- 4 types of transport vehicles based on 4 input nodes a, b, c, d as listed in “Factors leading to multi-vehicles”
- Number of people per vehicle calculated based on dimensions as given in automations.
- Space tug number calculation based on thrust needed as per Tsiolkovsky Rocket equation and as shown in **A.2**, results tabulated below.

CRITERIA	Boeing space tug	Benevectoras space tug
Carrying Capacity	Much smaller carrying capacity	Over 6 times as much thrust and larger in size and carrying capacity
Quantity Required	1044	18
Manufacturing cost	Manufacturing cost per space tug is less but the net cost will be a lot more	Manufacturing cost is comparatively more but since the number of tugs is way less, net cost reduces
Repairability	Hard to repair	Easy to repair
Fuel per tug	Less efficient fuel in larger quantity	Highly efficient fuel in less quantity

NUMBER OF SPACE TUGS	
a)Cargo	18
b)Passengers	2 (each holds capacity of 90 people at once)
c)Course Corrections	64
VEHICLES AT BENEVECTORAS	
Bicycles	700 (per segment)
Shuttle	20
CASSSCs required	52251
Number of Docks	12 Cargo, 2 IDSS

8

APPENDIX B: BIBLIOGRAPHY

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8

APPENDIX C:

COMPLIANCE MATRIX

NORTH DONNING HEEDWELL

COMPLIANCE MATRIX

		Requirements	Page no.
STRUCTURAL DESIGN	2.1	**Min. Req**	
		Exterior view (with major visible features)	2
		Rotating and non rotating sections	3
		Pressurised and non pressurised sections (indicating functions inside each volume)	3
		Implied Req.	
		Uses of large enclosed volumes in operational configurations	3
		Dimensions and design features of major components	3,4
		Provision of 0.38g in living areas	3
		Structural interfaces (between rotating and non rotating and on both sides)	5
	2.2	**Min. Req.**	
		Overall map of interior land areas (showing usage)	5
		Implied Req.	
		Uses, dimensions and orientation of interior down surfaces (with labelled drawings and allocated areas)	3,4

	2.3	**Min. Req**	
		Drawings showing 3 steps of settlement assembly to IOC and configuration	6
		Implied Req.	
		Processes required to construct the settlement	6
		When artificial gravity is applied	6
	2.4	**Min. Req**	
		Location of tug base on exterior view	7
		Tug dock configuration	7
		Implied Req.	
		Provision of a port/base for space tugs and course corrections	8
		Transfer of cargo and passengers	7
		Depiction of where tugs push on the structure on exterior drawings	8
	2.5	**Min. Req**	
		Locations of manufacturing areas on exterior view and internal map	8
		Implied Req.	
		Location and how en-route manufacturing and assembly capability is added	9

OPERATIONS AND INFRASTRUCTURE	3.1	**Min. Req**	
		Manufacturing location of component parts	10
		Implied Req.	
		Orbital location	10
		Sources of materials and equipment used in construction and operations	10
		Shipment in CASSSCs	10,11
	3.2	**Min. req**	
		Chart(s) and table(s) specifying CASSSC- loads required of commodities	11
		Implied req.	
		Atmosphere and climate (identification of air composition at 0.65 Earth sea level and quantity)	10,11
		Food production (location and growing condition)	11
		Electrical power generation (kilowatt distribution)	12
		Water management (water quantity and storage)	12
		Household and industrial solid management (recycling and/or disposal)	12
		Internal and external communication (devices and central equipment)	12
		Internal transportation system (routes and vehicles with dimensions)	13
		Day/Night cycles (how sunlight will be turned on/off in community areas)	13
		Initial quantities of air, water, food and other commodities	11,12
		CASSSC- loads required for each commodity	11,12
	3.3	**Min. Req**	
		Drawing(s) of primary construction machinery	14
		How it shapes raw materials/structural components into finished form	14

		Implied Req.	
		Designs of primary machines, jigs, and equipment	14
		Which asset will be used for IOC vs. operational construction	14
		How assets are shipped to IOC construction site	15
	3.4	**Min. Req**	
		Show size of tugs required to transfer identified number of CASSSCs	15
		Implied Req	
		Numbers and types of tug	15,16
		Tug design	16
		How CASSSCs are warehoused	15
	3.5	**Min. Req**	
		List of items to add infrastructure in Mars orbit and on the surface	17
		Implied Req.	
		Advisement on Mars Infrastructure	17
		Rovers and Aircrafts	17
		Shipment in CASSSCs	17
HUMAN FACTORS AND SAFETY	4.0	**Implied Req.**	
		Natural views of space outside	18
	4.1	**Min. Req**	

		Maps and illustrations depicting community design	19
		Location of amenities with a distance scale	18
		Dimensions of major features	19
		Implied Req.	
		Inclusion of offices, government buildings, meeting spaces, other community services, and agriculture as green space in public living areas	19,25
		Pressurised vertical clearance of at least 250 feet in living areas	19
		Locations and relative size of buildings	19
	4.2	**Min. Req**	
		External drawing and interior floor plan of at least five home designs	20
		Area for each residence design (in sq feet)	20
		Number required for each design	21
		Implied Req.	
		Floor plans of typical homes showing room sizes	20,21
		Home designs for permanent residents (min. 1000 sq. ft)	20,21
		Homes for in-transit Mars settlers	20,21
		Community map	19
	4.3	**Min. Req**	
		Identification in overall design separate volumes that can be isolated	21

		Implied Req.	
		Capability to isolate multiple habitable volumes in emergency	21
		Specification of spacesuit features, types and quantities	22
		Safety systems, devices	22
		Location of airlocks	23
		Protection from radiation and severe solar flares	23
	4.4	**Min. Req**	
		List of commodities to be manufactured	24
		Implied Req.	
		Identification and estimation of quantities of daily use commodities	24
		Location and storage of commodities	24
		Transfer to tugs	24
	4.5	**Min. Req**	
		Location of offices for in-transit settlers on interior map	25
AUTOMATION DESIGN AND SERVICES	5.1	**Min. Req**	
		Dimensioned drawings of automated construction and assembly devices (exterior and interior)	26,27
		Illustration of how devices operate	26,27
		Implied Req.	

		Uses of automation for construction	26,27
		Appropriate automation systems for assistance with transportation, delivery, equipment, assembly , installation and interior finishing	26,27
		How humans monitor and are required to interact with automated construction processes and progress	27
		How jigs hold robots in 0g	26
	5.2	**Min. Req**	
		Illustrations of control room for settlement monitoring and control	28
		Implied Req	
		Automation systems for maintenance, repair and safety	27,28
		Human intervention requirements (when and how)	28
		Means for authorised personnel to access data and command	28
		Description of safety measures to assure access of only authorised personnel (and their purpose)	28
		Privacy and control of personal data	28
	5.3	**Min. Req**	
		Dimensioned drawings of robots and computing systems	29
		Diagrams and networks to enable connectivity	30
		Implied Req.	
		Enhance livability, productivity and convenience	29
		Emphasis on use of automation for routine tasks	29

		Access to community computing assets and robot resources	30
		Robots max. 122 cm in height and not anthropomorphic	29,30
		Description of devices for personal deliveries	29
	5.4	**Min. Req**	
		size(s)/location(s) on interior map(s) of tug fleet control centers	31
		Implied Req.	
		Automated loading and unloading of CASSSCs	31
		Control center(s) for tug fleet and how it changes with the addition of tugs	31
	5.5	**Min. Req**	
		List of automation system types employed in manufacturing areas	33
		Implied Req.	
		Use of automation in manufacture and transport of commodities and Mars infrastructure items	32
SCHEDULE AND COST	6.1	**Min. Req**	
		Durations and completion dates of major design, construction and occupation tasks (in Gantt Chart with monthly or small increments)	34
		Implied Req.	
		Description of contractor tasks	36
		Schedule date(s) for move into new homes	34
		Establishment of population at completion	36

	6.2	**Min. Req**	
		Spreadsheet(s) listing costs associated with diff. phases of construction (clearly showing total costs)	35
		Implied Req.	
		Specification of costs billed per year (in USD)	35
		Estimation of number of employees working during each phase	35
BUSINESS DEVELOPMENT		**Port for space tugs**	
		Course correction of Space Tugs and transfer	37
		Rapid loading and unloading	37
		Safe and convenient transfer between artificial gravity and 0g	38
		Manufacturing commodities for use on Mars	
		Provision of excess capacity for manufacturing commodities on Mars	38
		Specification of quantities and types of agricultural products for transfer to Mars and loaded in CASSSCs	38
		Manufacturing for Mars Infrastructure and trade with Earth	
		Identification of infrastructure items	39
		Components of raw materials required	39
		Mars products for cis- lunar use	40
		Capability to refine Mars ore	40
		Tank capacity for transporting deuterium to Earth	40
APPENDICES	A	**Operational Scenario**	

		Trade study to determine the number of tugs and transfer vehicles	41,42
		Factors and scoring methodology to determine the number, types, docking system and number of CASSSCs/people accommodated	43,44
	B	**Bibliography/ References**	
		Cite references and specifically refer source materials	45,46, 47,48
	C	**Compliance Matrix**	
		Lists each requirement in SOW and specifies the pages	49,