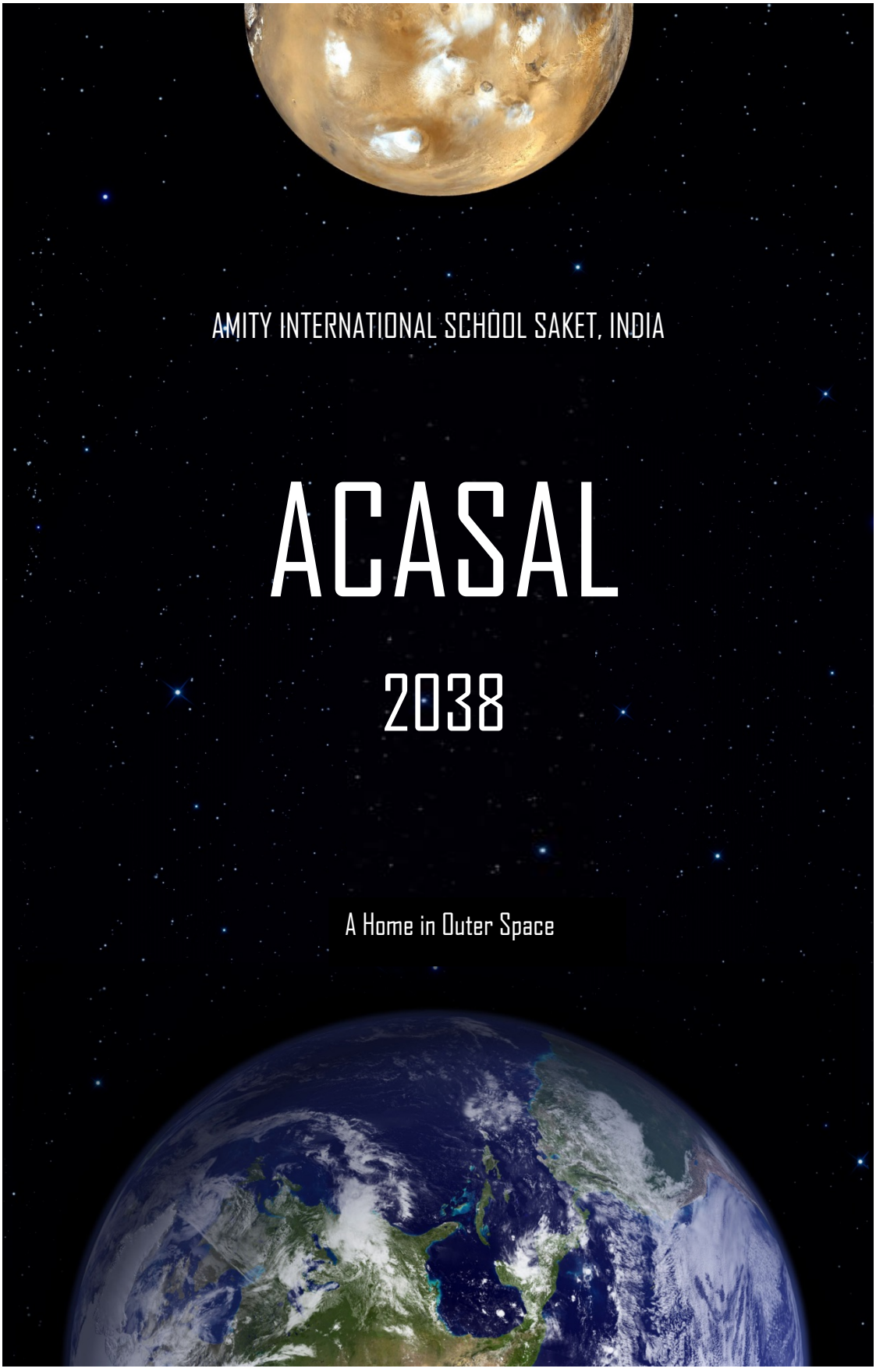
AMITY INTERNATIONAL SCHOOL SAKET, INDIA
ACASAL
2038
A Home in Outer Space

25th Annual International Space Settlement Design Competition
Proposing Team Data 2018

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I understand that if our Team qualifies for the ISSDC Finalist Competition July 27-30, we will be expected to finance our own travel to/from Titusville, Florida, USA.

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18/4/2018
Date

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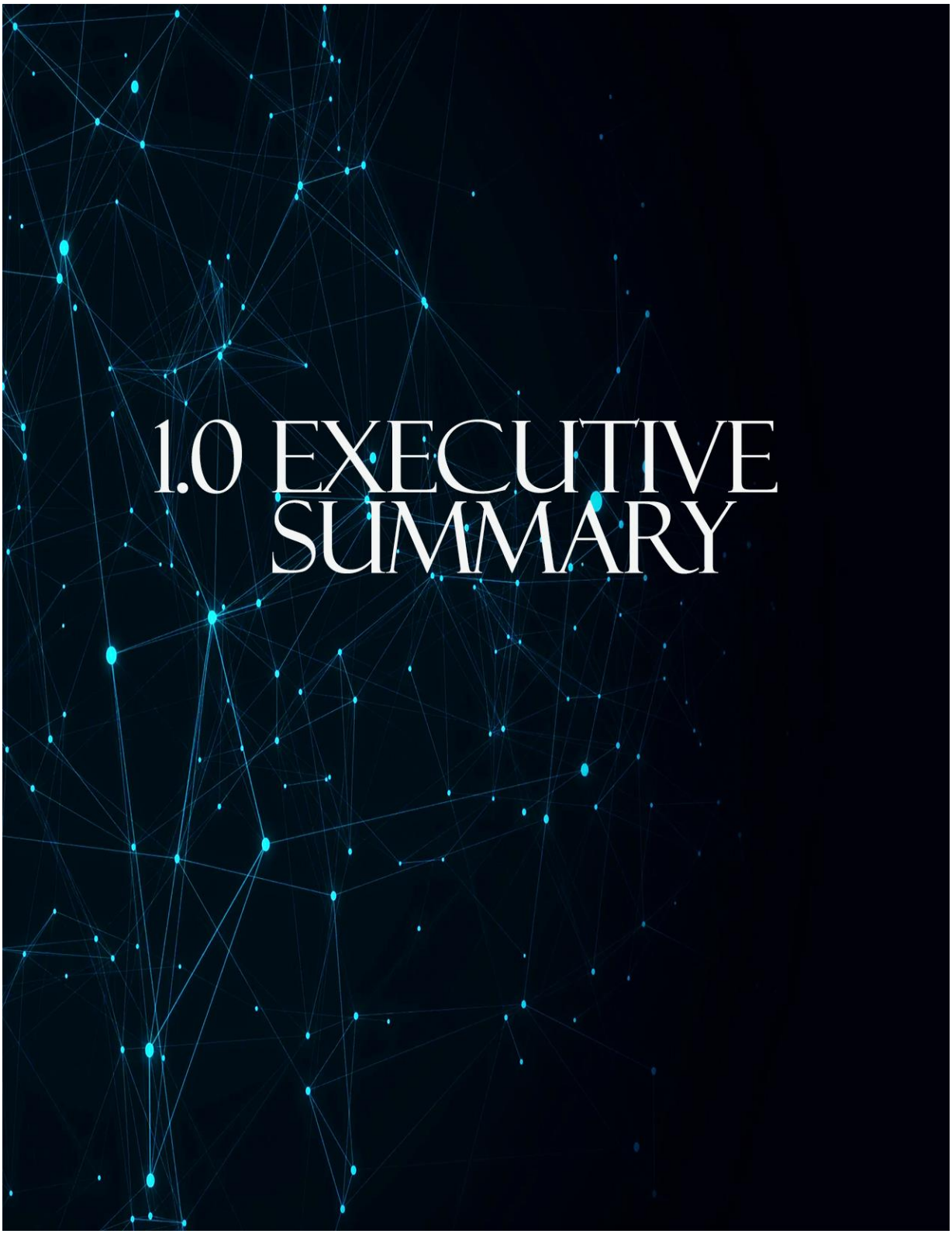

1.0 EXECUTIVE
SUMMARY

"How beauteous mankind is! O brave new world, that has such people in it!."

- William Shakespeare, The Tempest

Acasal (*a'casa' , a home around luna*) is proposed with a goal in mind- to take advantage of one of the most promising economic ventures of the 21st century, the expansion of space infrastructure. This design is avant-garde in space settlement design as well as industry, the nexus between our present, and the future of a space-faring civilization, beginning with its first steps on Acasal.

To best serve the Foundation Society, a myriad of constructive features have been incorporated in the settlement's design, of which the salient ones include:

I. An innovative structural design paradigm, providing 8 different g-levels within the residential cylinder, *Singularity*, without using coaxial cylinders.

II. Stability provision due to the opposite (though equal in magnitude) rotation of the the two cylinders in Acasal's structure- *Singularity* and *Hubble*, which negates rotational tendencies that may be inflicted on the overall structure.

III. LED windows in homes, thereby allowing residents to customize views. Moreover, external repairs is being done using robots and virtual reality, which ensures the safety of humans without compromising the view of the external rotating volumes.

IV. A gym with base equipment for cardio exercises in every house in low-g areas, as residents are likely to burn fewer calories in day-to-day activities in such areas. This also generates electricity from excess kinetic energy.

V. An efficient automated hydroponic-aeroponic hybrid modular grid system for agriculture, which works efficiently at different g-levels.

VI. A Biological Control System (BCS) instead of traditional methods for CO_2 scrubbing, which will also serve as a source of oxygen and food.

VII. Intricate systems for waste and water management, which, together, minimize the waste generated onboard the settlement, recycling and decomposing wastes in several cases.

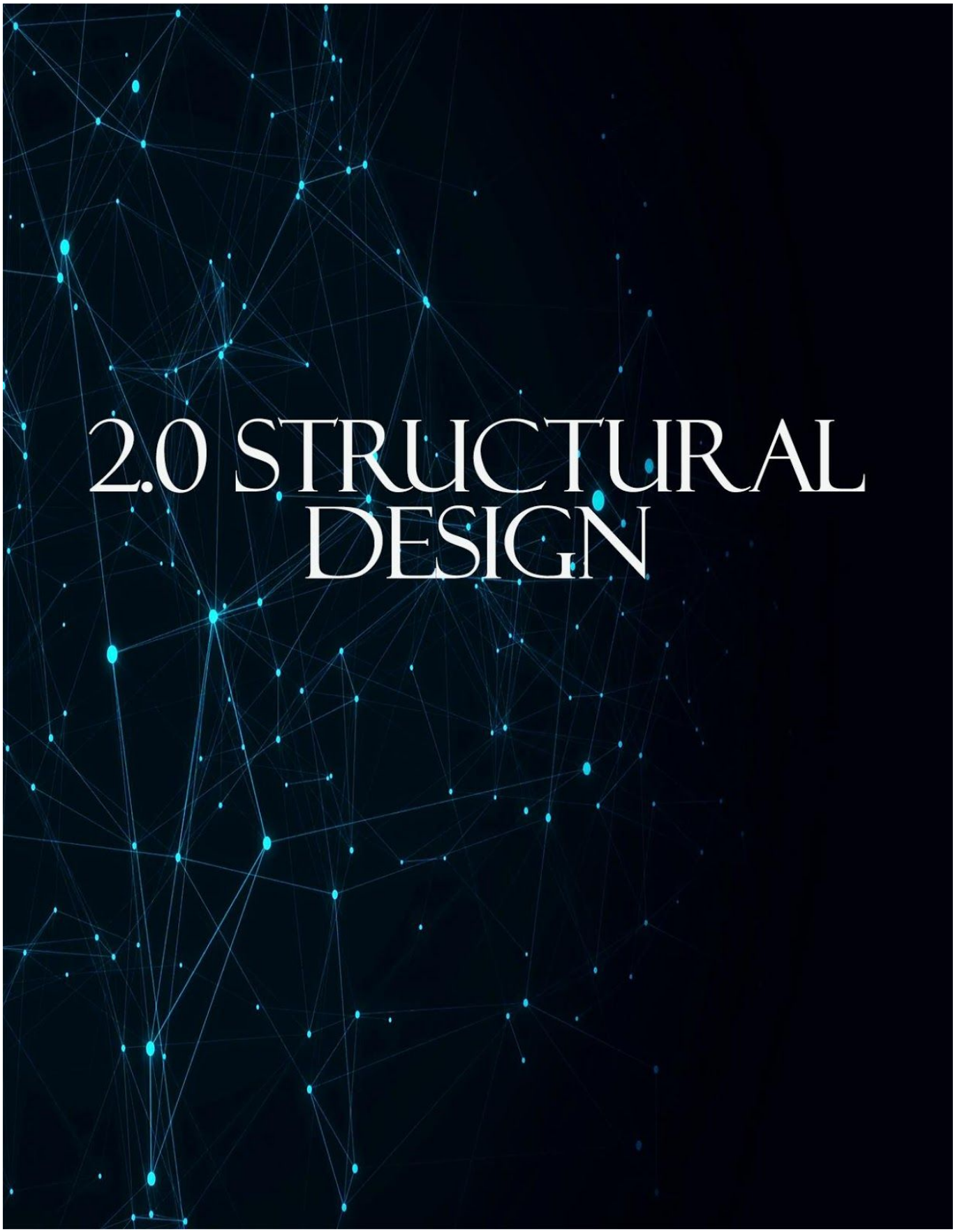
VIII. The usage of specialised towers known as *chirals* that provide the g-levels within *Singularity's* interior design as opposed to coaxial cylinders, which in turn restrict freedom in the settlement.

IX. The usage of low-cost mass production methods for bots like the inspection bots. These need little effort for launch and allow effective information transfer to the settlement.

X. For research purposes, *Acasal* will have agriculture at different g levels to find the optimum conditions to facilitate growth.

Therefore, we are proud to present Acasal- an innovation for living and a revolution for humanity.

Ad astra per aspera.


2.0 STRUCTURAL
DESIGN

2.1 Major Structural Components and Design Features

I. To prevent distortion of structural design due to strain, the structural design perpetuates symmetry as its existence enables the design to maintain its geometry when under load (*Macdonald, 2007*).

II. Cylinders chosen as the principal components of the design are the most appropriate shape for a space settlement. This is because out of all shapes, cylinder has the least mass for the same amount of down surface area; As settlements have an overwhelming amount of mass, lower mass becomes a major positive factor. Moreover, except sphere (rotationally unstable), cylinder provides the maximum internal volume.

III. For a rotationally stable cylinder, the following must be true

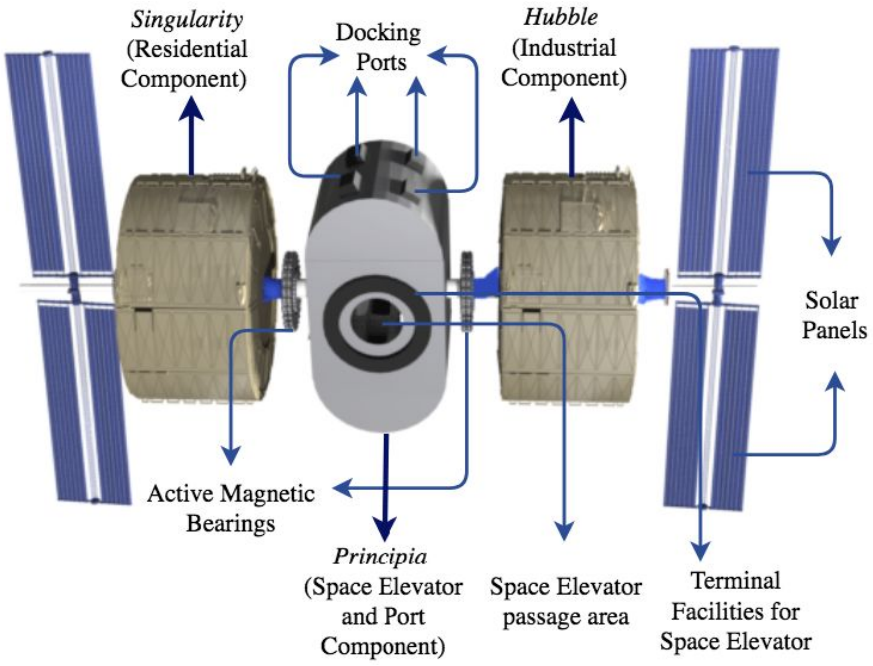
$$Iz = (1.2)\, Ix$$

Where Iz = Moment of Inertia along z axis, and Ix is Moment of Inertia along x axis

To fulfill the condition, the height to radius ratio is kept at 1.3 for all cylinders.

IV. *Theodore Hall, 2015* - Study on Space Settlement Rotation tolerance, suggests that rotational angular velocities above 2 rpm adversely affect human health. Thus, the angular velocity is kept at 2rpm. As an added benefit, the Coriolis effect is insignificant at 2 rpm and below.

V. The residential cylinder, *Singularity*, contains the population's residence, and automation and food storage. For *Singularity*'s interior design, we opted to not go with coaxial cylinders (that restrict freedom in the settlement), and rather designed columns/towers called *chirals.* within the residential cylinder that provide 8 different g levels while not compromising on the openness.



VI. The industrial cylinder, *Hubble*, also hosts an array of g levels through a design containing multiple coaxial cylinders. *Hubble* hosts agriculture, shuttle manufacturing operations, and refining and processing units for lunar materials. *And in transit CASSCS.*

VII. The Port and Space Elevator Component, Principia, is a cube with two faces covered by semicircular prisms. The component hosts ports and provides functions for space elevator.

VIII. Central Shafts of Hubble and Singularity merge with the ring within Principia to provide the main transportation channel in the settlement. *Refer to section 7.1 for details on Central Transportation System.*

IX. The Settlement has alternate stretches of windows at the ends of the cylinder

providing projections of natural views of Earth and Luna. *Refer to Section 4.2 for details on placement of windows in community layout.*

X. The Settlement has thrusters for station keeping and providing torque, if required, to maintain rotation of cylinders.

XI. Both cylinders, *Singularity* and *Hubble*, rotate in opposite directions (with same magnitude of angular velocity) which negates rotational tendencies that may be inflicted on the overall structure, providing stability.

2.1.1 Structural Dimensions

Component	Sub - Component	Dimensions
Residential Component (*Singularity*)	Cylinder	Radius = 223.23m Height = 290.2m Total Volume = $4.5*10^7$ m^2
	Chiral (Cylindrical Towers)	Radius = 10m Height = 212.7m Volume = $6.6*10^4$ m^2

Table 2.1.1.1 Singularity Dimensions

Purpose	Sub - Comp.	Dimensions
Industrial Component (*Hubble*)	Outermost Cylinder	Radius = 223.2 m Height = 290.2 m Volume = $7*10^6$ m^2
	Mid Cylinder	Radius = 74.41 m Height = 290.2 m Volume = $3.8*10^6$ m^2
	Innermost Cylinder	Radius = 37.2 m Height = 290.2 m Volume = $1.2*10^6$ m^2

Table 2.1.1.2 Hubble Dimensions

Component	Sub-Comp.	Dimensions
Port and Space Elevator Component (*Principia*)	Cube (with hole)	Side = 100 m Hole (r=26m, h=100m) Volume = $7.88*10^5$ m^2
	Semicircular prism	Radius = 50 m Height = 100 m Volume = $7.8*10^5$ m^2

Table 2.1.1 Principia Dimensions

Fig 2.1.1.1 Interior of residential component

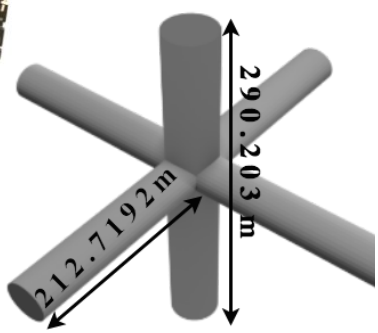


Fig 2.1.1.2 Dimensions of Chirals

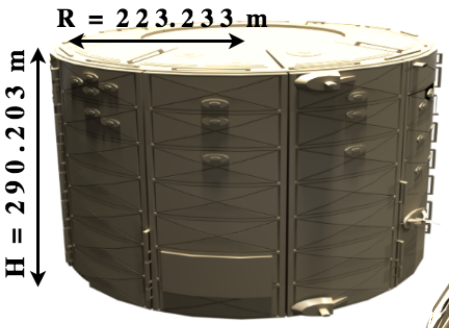


Fig 2.1.1.3 Dimensions of both *Singularity and Hubble* Cylinders

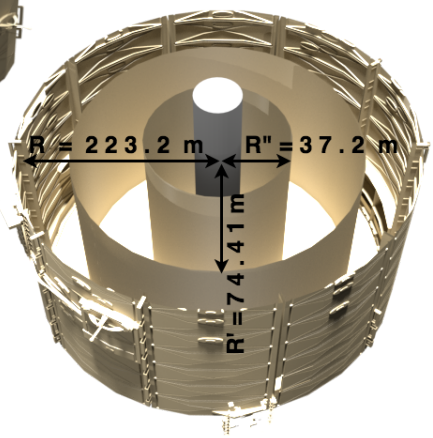


Fig 2.1.1.4 Dimensions of *Hubble*'s coaxial Cylinders

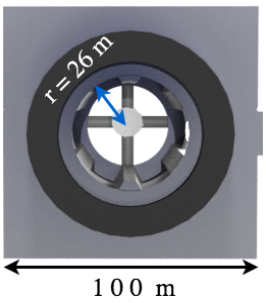


Fig 2.1.1.5 Dimensions of Principia's Cube

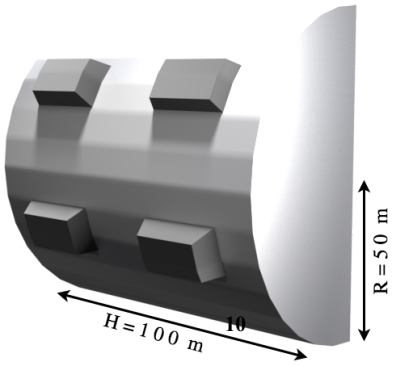


Fig 2.1.1.6 Dimensions of Principia's Semicircular Prism

2.1.2 Rotation and Artificial Gravity

2.1.2.1 Angular Velocity

As previously mentioned, humans subjected to a rotation speed of 2 rpm or above tend to display stressful behaviour and sickness. Also, we had to use the maximum possible value of angular velocity

$$a = \omega^2 r$$

Where, a is Centripetal Acceleration
ω is Angular Acceleration
And r is Radius

As angular acceleration increases, Radius decreases for same g level which lowers the construction cost. Hence Angular velocity is kept at **2 rpm.**

2.1.2.2 Coriolis Effect

$A_{CO} / A_{CP} = 2 V_{O(RR)} / V_T$

Where, A_{CO} is Coriolis Acceleration
A_{CP} is Centripetal Acceleration
$V_{O(RR)}$ is Velocity of object (with respect to rotating structure)
V_T is Tangential Velocity

Thus, Increasing the tangential velocity minimises the coriolis effect. *Hill & Schnitzer 1962, Gordon & Gravias 1969, Cramer 1985* are studies on rotation that placed optimal tangential velocities above 6 m/s, 7m/s, 7 m/s respectively.

For the same rotation i.e. 2 rpm, tangential velocity decreases with decreasing radius as

Tangential Velocity = Angular Vel. × Radius

Therefore, the down surface area with least radius (37.2 m) has least tangential velocity i.e. 7.79 m/s. Thus, all values of Tangential velocities are above this i.e. well above optimal values.

Therefore, the coriolis effect is negligible at 2 rpm.

2.1.2.3 Different g levels within Settlement

- Residential Cylinder

The cylinder (excluding the chirals) has only one continued down surface i.e. the inner curved surface area (no coaxial cylinders) having a gravitation of **1g.**

This cylinder has 4 chirals (cylindrical towers) placed on its inner curved surface. Each chiral has 8 floors within it and it runs from the bottom floor (having artificial gravity of 1g) to the top, till the central shaft, that is the 8th floor (having artificial gravity of ⅛ g). *Refer to section 2.2.1* for detailed explanation on placement and dimensions of chirals and the residential cylinder.The 8 floors of the chirals along with their g levels are described in *figure 2.1.2.3.*

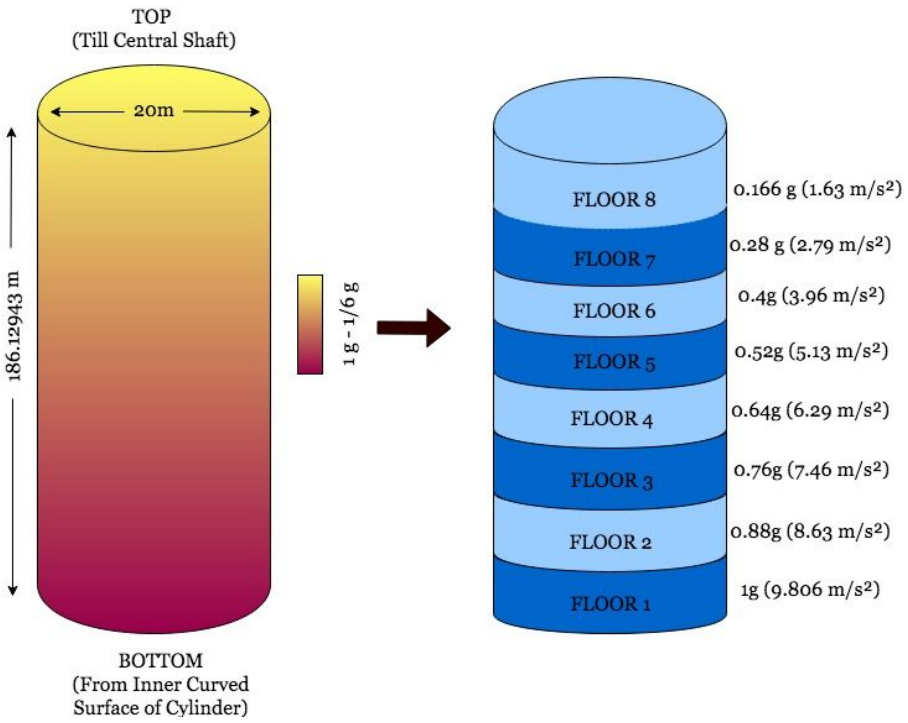


Fig 2.1.2.3.1 - G Levels within chirals
(the figure does not represent the residential cylinder)

- Industrial Cylinder

The cylinder has coaxial cylinders that are designed to provide differing g levels in the cylinder for industrial operations. Details of g levels are provided in *figure 2.1.2.3.2.*

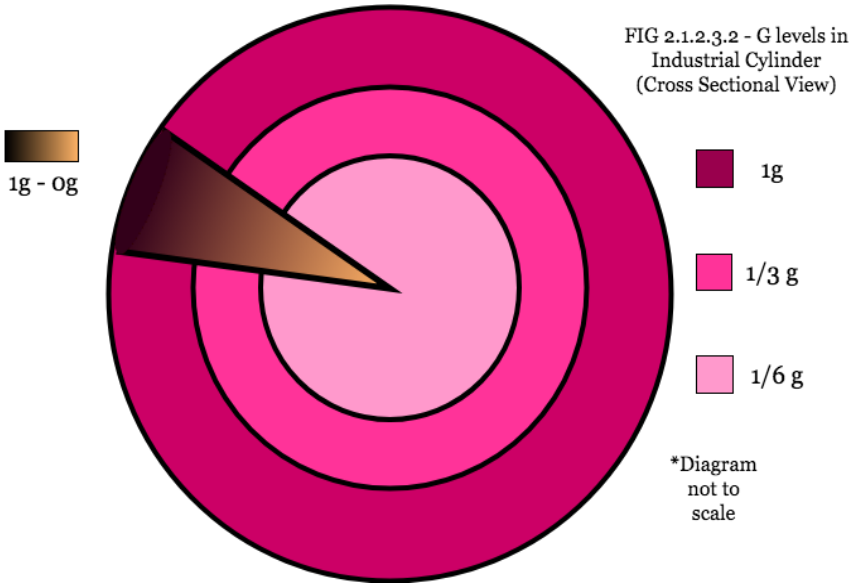


FIG 2.1.2.3.2 - G levels in Industrial Cylinder (Cross Sectional View)

2.1.3 Interfaces between Rotating and Non-Rotating Components

Mechanical Bearing (MecB)	**Active Magnetic Bearing (AMB)**
Physical contact between bearing and shaft causes enormous frictional losses	Lack of contact causes reduced the system friction
Constant maintenance required due to wear	No wear of bearings eliminates need for maintenance
Low costs	High costs

Table 2.1.3 Trade Study (AMB vs MecB)

Thus, we use Active Mechanical bearings for ensuring increased efficiency. In this mechanism, the rotating shaft levitates and is held in the centre (to avoid physical contact) through provision of controlled electromagnetic forces on the shaft. Furthermore, sensors monitor the distance between the shaft and the bearing and accordingly adjust the current, used to apply these forces and levitate the shaft.
Refer to *Figure 2.1.3* for rotating and non-rotating components of the structure.

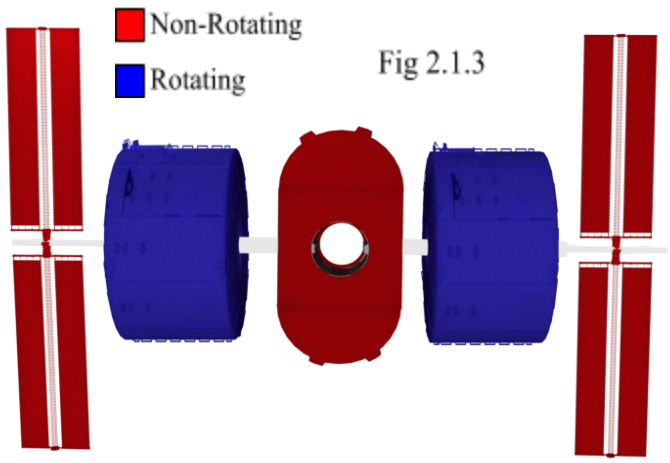


Fig 2.1.3

2.1.4 Pressurised areas and non pressurised areas

Singularity and some parts of principia are pressurized at 10.29 PSI (0.7 atm). some parts of principia, i.e areas directly in contact with the lunar elevator portal like main dock radar room, cavity area, etc. are left unpressurized which shall also save fuel and improve efficiency as well as prevents any unnecessary harm to the stored goods. Due to the automated nature of these areas, human entry is infrequent. Some areas in *Hubble,* for example, CASSC warehousing areas are not pressurized while the agriculture zone is pressurized at 16.5 PSI (1.15).

2.1.5 Isolation Sequence in Emergencies

The isolation sequence is initiated on detection of breach and based on thermal, visual analysis, and strain measurement, an approximate time to complete breach is estimated. Depending on this time, population is directed to contingency pods. *For details, refer to section 5.2.2.*

The residential cylinder gets isolated into 37 separable habitable volumes.

- ➔ There are a total of 4 chirals, with 8 floors each. Every floor islotes into a distinct volume creating 32 separable volumes.

- ➔ The main cylinder itself is divided, cross sectionally, into 5 cylinders.

2.1.6 Natural Views of Earth and Luna

Along with the windows in the residential cylinder, one of the cuboidal cavities (*explained in section 2.2.2*) is a deck for providing natural views of Earth below and Luna above. For features of the deck, *refer to section 5.0*.

2.2. Internal Allocations and Structural Components

2.2.1 Residential Cylinder: Singularity

The component has a cylinder (not coaxial) with chirals within.The chirals are cylindrical towers with their bases placed on the down surface area of the cylinder extending till the outer of central shaft. There are 4 chirals, placed exactly halfway on the height of the cylinder and at angle of 90°.

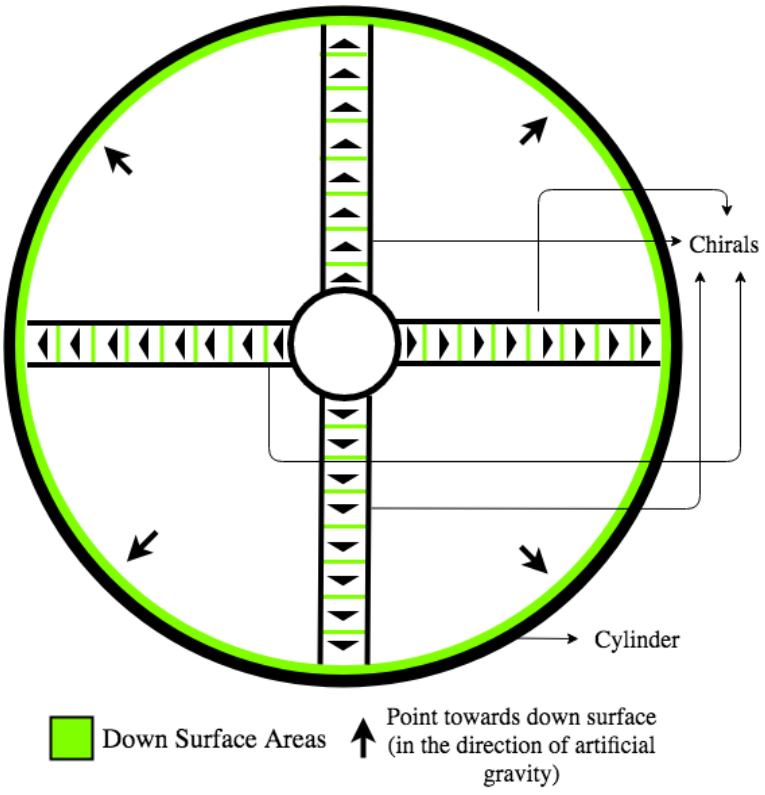


Fig 2.2.1 Cross Sectional View of *Singularity*

Purpose	Area (in m^2)	Percentage
Housing	374310.343	89.81%
Recreation	929.0304	0.222%
Entertainment, Mall	1393.5456	0.334%
Community Center	1393.5456	0.334%
Green belt, Park, Open Spaces	37161.216	8.91%
School, University	557.4182	0.133%
Hospital	278.7091	0.066%
Police Station	185.8061	0.044%
Library, Museum	557.4182	0.1333%

Table 2.2.1 Singularity Area Allocations

Down surface area of Singularity = **406713.91 m^2**
(Chiral bases excluded)
Down surface area of Chirals = **10053.08 m^2**
(Chiral bases included)
Down surface area total = **416766.99 m^2**
Vertical Clearance of cylinder = **446.46 m**
Vertical clearance of each floor in chiral = **26.5899 m**

2.2.2 Space Elevator and Port Cube: Principia

Deciding Principia's Design	
Cylinder	**Cube**
A hole being carved in a cylinder component presents manufacturing difficulties.	Carving hole on flat cube surface is comparatively easier.
Provides more curved surface preferred for sustaining strain.	Provides no curved surface area.

Table 2.2.2.1 Trade Study (Cube vs Cylinder)

Therefore, a hybrid of the 2 designs is chosen.

The design is a mid cube component with semicircular prisms covering its 2 opposite faces. The cube has a cylindrical hole allowing the space elevator to function. This cube (with the hole) has cuboidal cavity on the inner surface of the hole acting as **stations** for boarding or alight the space elevator while one of them is an observation deck.

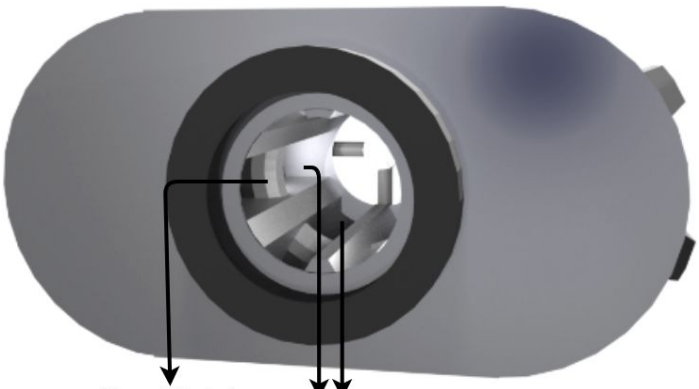


Fig 2.2.2 Principia Design

A torus passes through all these cavities (passing through the walls between them), and the central shafts of *Singularity* and that of *Hubble* get connected to this torus providing a complete connection system through the settlement.

The Semicircular prism ends have 4 ports each connected directly into the inner ring of cuboidal **stations**.

Purpose	Volume (in m^3)	Percentage
Ports	785714.28	44%
Space Elevator	42491.42	2.37%
Space Elevator Stations	820721.64	45.96%
Observation Deck	136786.94	7.67%
Total	1785714.29	100%

Table 2.2.2.2 Principia Volume Allocations

2.2.3 Industrial cylinder: Hubble

The component has coaxial cylinders providing gravity at 1g, 1/3g and 1/6g. The cylinders is meant for warehousing (especially for CASSCS), Agriculture, material refining and shuttle manufacturing processes.

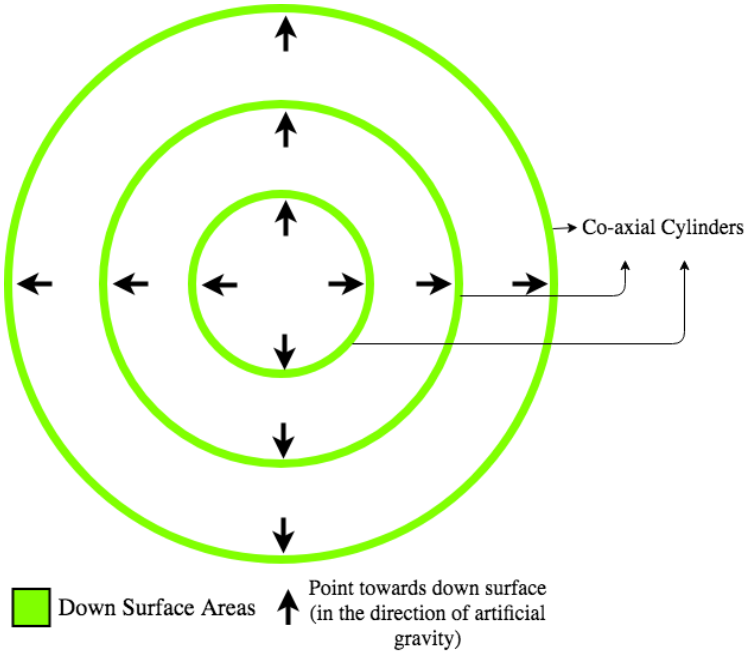


Fig 2.2.3 Cross sectional view of *Hubble*

101801.915

Purpose	G level (area in m^2)			Total
	1g	**1/3 g**	**1/6g**	
Agriculture	67867.93	45245.28	22622.64	137735.85
Warehousing	0	0	45245.28	45245.28
Space Shuttle Manufacturing	61081.14	54294.34	0	115375.48
Material Refining	40720.76	81441.52	0	122162.28
Automation and Bot Storage	101801.905	33933.96	0	135735.86

Operational Storage	135 735. 87	4524 5.29	0	180981 .16
Total	407 207. 62	1357 35.87	67867 .93	610811 .42

Table 2.2.3

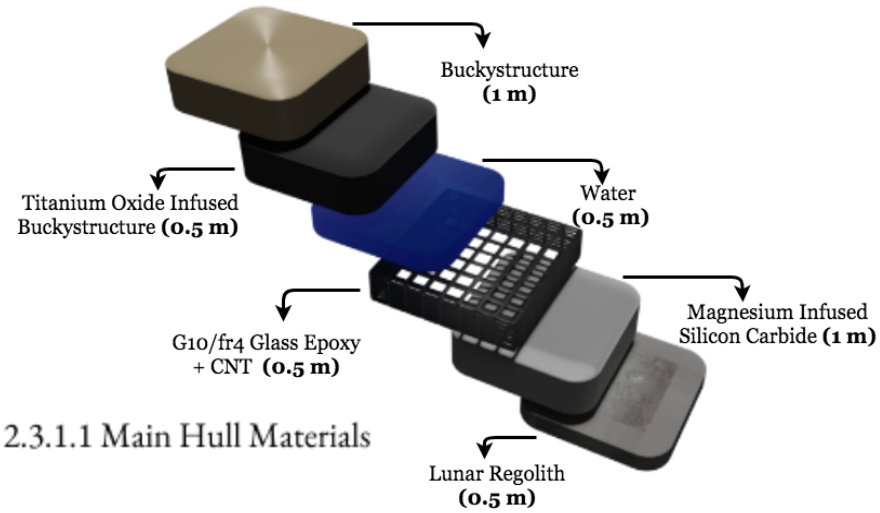
Total Down Surface Area = **610811.42 m²**
Vertical clearance of Innermost cylinder = **37.2 m**
Vertical clearance of Mid cylinder = **37.2 m**
Vertical clearance of Outermost cylinder = 1**48 m²**

The chosen 3 levels allows simulation of **Earth like**, **Mars like** and **Moon like** gravitational condition and allow testing of critical operations in these conditions, laying out the **foundation for research on on-surface settlements**. These 3 levels also open up scope for **research through experimentation** on **agriculture in different g levels**.

Maximum **warehousing in ⅛ g** area allows **easy handling** of CASSCs and a means of **quick connection to *Principia***.

2.3 Settlement Construction

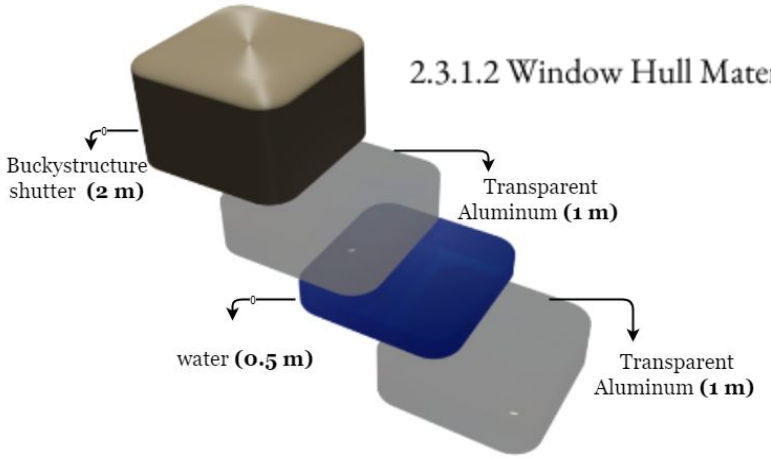
2.3.1 Hull Materials



2.3.1.1 Main Hull Materials

Material	Usage
Buckystructure	They are exceptionally strong in tension and can tolerate the space environment.
Titanium oxide Infused Buckystructure	This is a very lightweight and strong material.It can be used for thermal insulating.
Water	Helps to reduce radiations and heat.
Magnesium Infused Silicon Carbide	It has a high strength to weight ratio which will provide us with high structural integrity.
Lunar regolith	Used for shielding the settlement from harmful radiation.
Transparent Aluminum	It is transparent and would be used in the windows.

Table 2.3.1 Hull Material Usage



2.3.1.2 Window Hull Materials

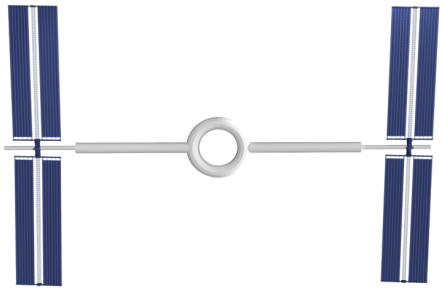
2.3.2 Maintaining Settlement Rotation

VASIMR Thrusters are used to maintain rotation and settlement position. *Refer to section 3.4 for details.*

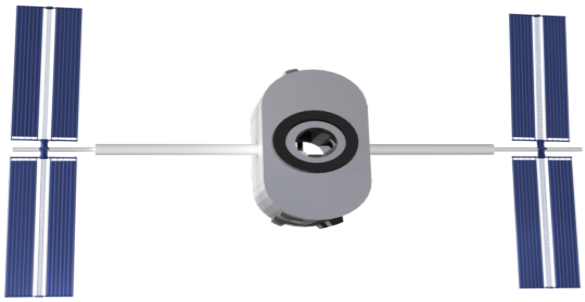
2.3.3 Phases of Construction

Preconstruction Phase: The central shafts and torus will be prefabricated, and transported in different parts. One of the piece having the central torus attached to it. All these pieces will be transported in separate space shuttles. As these parts are hollow, they will carry Porphyrion and materials for further construction.

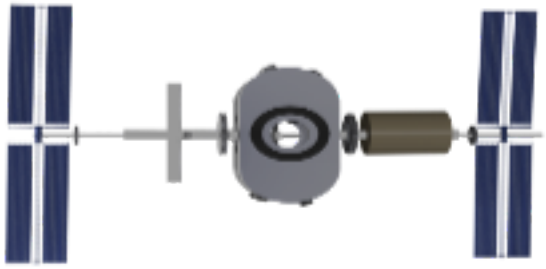
Phase 1: Porphyrion and Nano Bots will work together to weld the different pieces to form the central shaft with the torus. They will also install solar panels simultaneously. This will provide the required energy to further facilitate the working of the robots and construction. Construction of Two docking ports and mesh of Principia will be initiated in Phase 1.



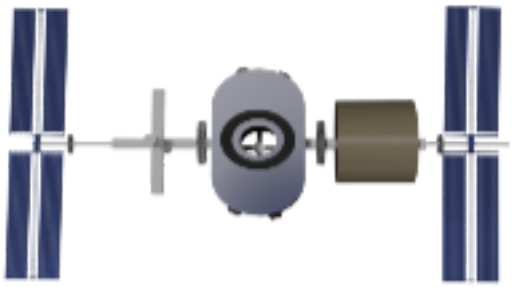
Phase 2: Skeletal structure of Principia will be built. The construction of remaining Dock ports, Chirals and Hubble will commence. Space Elevator Functions will be operational which will help to provide the materials from earth and the moon required for further construction. The Two Docking ports will be functional in this phase



Phase 3: Construction of the innermost cylinder of Hubble and Ports will be completed. Initial Operating Capability will be established. Rotational capacity will be achieved in Hubble. Interior construction of Chirals will begin. Pygmies will begin their work in the areas completed. CAASCs will be imported.

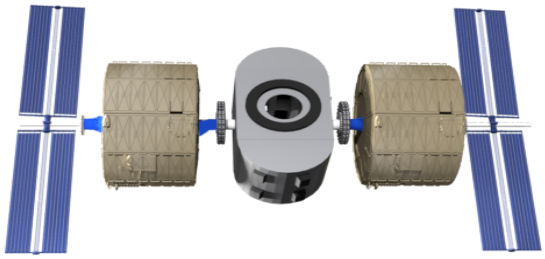


Phase 4: Chiral construction will be completed. Singularity construction will commence. All 8 docks will now be functional. With the innermost layer of Hubble with interiors completed, cargo shipping will begin giving priority to the agricultural setup. Hubble's Mid cylinder will be completed.



Phase 5: Construction of outermost cylinders of Hubble and singularity will be finished and Interior construction of Singularity will be initiated which will provide the first living quarters and life support systems. This will allow the first batch of Humans to be transported to the settlement and check its functioning.

Phase 6: Interior construction of Hubble will be completed. Interior Construction of Singularity will be underway. All processes and life support systems will be thoroughly tested to ensure their success. Preparations for welcoming the residents will be commenced. Their cargo will be imported.



Phase 7: Construction of Singularity along with Acasal will conclude achieving full functionality.

2.4 Space Elevator Operations

The middle component, *Principia*, has a hole in the cube to allow the space elevator to fit inside. One of the ends of the hole has a cross on the center of which, the cable attaches. This enables the settlement to act as a counterweight for the space elevator. The space elevator can fit inside and the cuboidal cavity act as unloading/loading stations which have entrances to the central transportation torus component, creating a rapid transportation system.

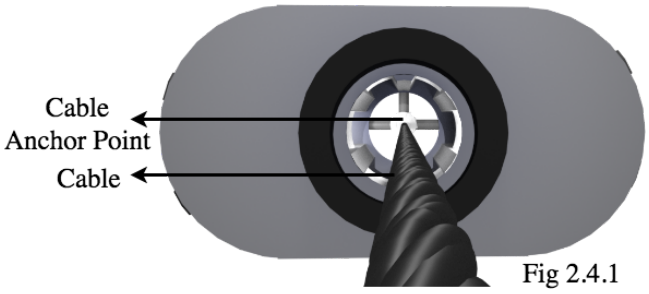


Fig 2.4.1

The terminal facilities are added on the exterior of the cube in vicinity of the hole. The facilities are short term cargo and passenger holders. They contain primitive structures for humans to reside in for 3-4 hours and for cargo till it is transported to the main storage in *Hubble.*

2.5 Port Facilities

2.5.1 Configuration

Acasal provides 8 port docks in 0g in *Principia* enabling easy docking of ships from LEO and lunar surface.

2.5.2 Initial Operating Capability

IOC established in phase 3. Four operational docks and terminal facilities, in Principia, and storage in Hubble are available.

2.5.3 Types of Docks

Acasal enables lunar landing shuttles to be more efficiently operated and maintained through one large orbital base instead of multiple depots in various orbits. Therefore it accounts various types of docks for different purposes

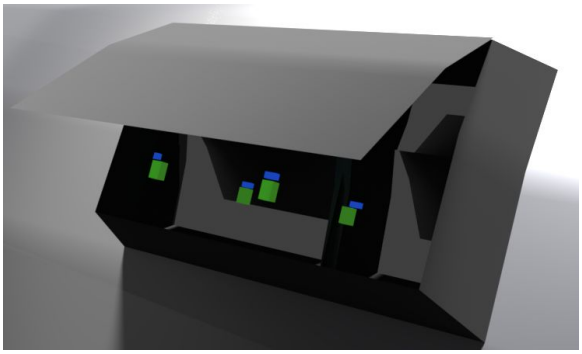


Fig 2.5.3 Port Entry

1. **Cargo ports:** Acasal has two cargo ports. Each port allows ample room for large spacecraft and transport of goods. Transports cargo (in both containers and in bulk) between Lunar landers and larger space crafts. They are larger than passenger ports and need to accommodate large cargo ships.

2. **Passenger ports:** Acasal has two passenger ports for movement of people from/to LEO spaceports and the lunar surface. Docking and safe transportation into residential cylinder for transient and permanent population

3. **Multi purpose ports:** There are 3 multi purpose ports in Acasal which will serve for all purposes depending on availability and requirements. As the customer are our first priority, these ports will majorly work as passenger ports. They shall also accommodate small cargo ships

4. **Backup port:** There is 1 backup port in acasal which shall serve its purpose during contingency or when no ports are available. It is therefore built as a multipurpose port.

2.5.4 CASSC and Cargo Warehousing

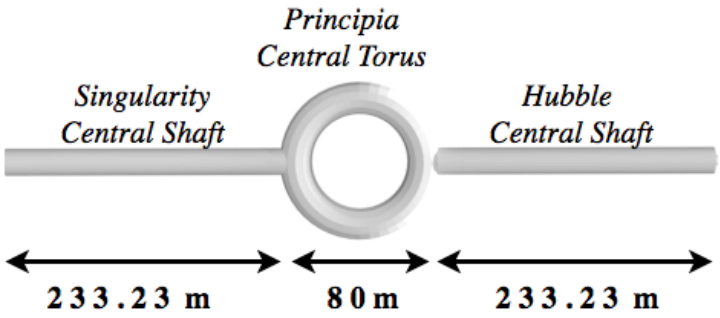
As mentioned previously, terminal facilities provide a temporary storage and they are then transported to *Hubble* for warehousing. *Refer to section 5.5 for warehousing details.*

2.5.5 Customs

After the cargo is transferred, it will immediately be checked by security bots and undergo decontamination processes, all automated, only supervised by human operators, since security and safety of the residents are of the highest concern. As for the passenger ships, they will use a larger airlock when they board the Acasal, Then will undergo a scanning process. Then they will proceed to a decontamination chamber where examinations will be conducted by nanobots to check for any diseases or lunar dust. After that, they will step out onto the pressurized dock and will be given necessary equipment and documents including space suits, Acasal visas and guidelines. After that, they are free to enjoy the natural views provided by Acasal while in hubble or singularity

2.5.6 Central Transportation

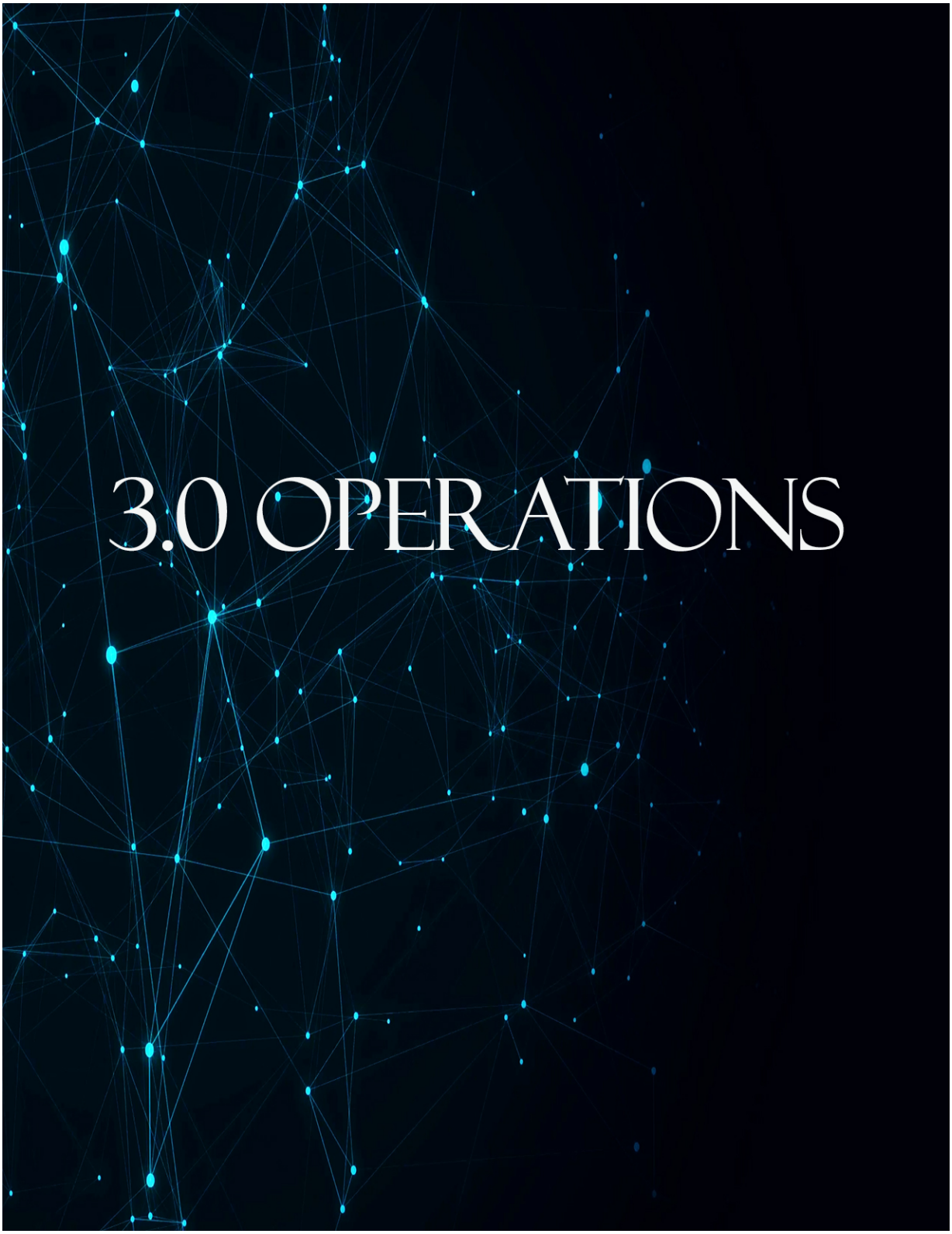
Transportation is carried out through means of the central shafts and the central torus. *Refer to section 7.1 for details.*



The transportation system provides a direct link between ports, space elevator Stations, *Singularity* and *Hubble* through a system of elevators traversing these channels. The central shaft and torus is kept depressurised from the inside to avoid creation of pressure differentials due to movement of elevators within these channels which may cause the structure to destabilise.

Component	Sub-Comp.	Dimensions
Central Transportation system	Central Shafts	Radius = 10.61 m Height = 233.23 m Volume= 82483.11 m^3
	Central Torus	Major radius = 80 m Minor radius= 70 m Volume = 7740000 m^3
Total Volume	= V(Central Torus) + =2[V(Central Shaft)] =[7740000 + 2 (82483.11)]m^3 = **7904966.22 m^3**	

Table 2.5.6 Central Transportation System Dimensions


3.0 OPERATIONS

3.1. Location and Materials

3.1.1 Orbital Location

Acasal is located at the Earth-Luna L1 libration point. The settlement location and resource management on Acasal maximises the usage of terrestrial resources and materials from Alexandriat and near-Earth asteroids. This location due to the following reasons:

- It has negligible variation in velocity which therefore allows smooth entry to Lunar and Earth Orbits. This gives a benefit to place Acasal to support the movement of personnel and help in carrying the cargo to the moon and back to Acasal.
- Acasal can be made to accomplish a small orbit about this point with a very small outflow of energy.

The construction of the settlement is based off of a prefabricated port unit that is brought to the settlement from Earth. In initial stages of construction, the port is fairly large and can house various robots and machinery to produce the rest of the settlement.

3.1.2 Construction Materials

Materials	Source	Uses	Volume
Materials for settlement			
Buckystructure	Moon	Outer wall	790976.48
Titanium oxide infused buckystructure	Moon	Strong and easily feasible	790421.97
Water	Earth	Protection from solar radiations	416647.95
G10/fr4 glass epoxy + CNT	Earth	Light weight	408687.05
Magnesium infused silicon carbide	Moon	Lightweight and easily available in moon	787111.28
Lunar regolith	Moon	Beneficial for internal construction	402147.96
For windows			
Buckystructure shutter	Moon	Outer wall	12703.04
Transparent aluminium	Moon	Transparency and strength	12203.64
Water	Moon	Protection from solar radiations	3175.76

Table 3.1.2. Construction Materials

3.2. Elements of Infrastructure

3.2.1. Atmosphere

Note: - Studies have shown that plants grow with atmospheric CO_2 concentrations up to 1500 ppm instead of what Acasal's residential atmosphere provides (~330 ppm). This has accordingly been accounted for in the agricultural units. Given a pressure of ~10.28 psi in residential areas, lower than that of Earth, the percentage of oxygen in the atmosphere is kept higher than that of Earth. This ensures a similar effective oxygen level.

Component Production

Oxygen is going to be provided via photosynthesis from both the agricultural sector and the algae tanks. It will also be provided by the electrolysis of the water obtained from the Bosch reaction as well as the general excesses of water aboard Acasal. This will be supplied in a larger quantity to the residential atmosphere as the lower pressure would otherwise result in a lower effective oxygen level. As per NASA's '75 summer study, partial pressure of O_2 should be high enough that partial pressure within the alveoli of the lungs for good respiration yet low enough to avert losses and large changes in number of microorganisms.

Carbon dioxide will be obtained primarily through the passive process of respiration, while active processes like the Zimmerman process, the Bosch process, as well as other industrial and biological processes contribute to the supply on a smaller scale. This will be in permanent circulation, given its importance to agriculture and the possible

Gas	Percentage	Mass (tonnes)	Storage (CASSSCs)
Nitrogen (N_2)	74.14%	42,135	177
Oxygen (O_2)	24.6%	15,966	59
Carbon Dioxide (CO_2)	0.033%	29.6	1
Other Gases	1.227%	992	3

Table 3.2.1.1. Residential Atmosphere Composition

Gas	Percentage
Nitrogen (N_2)	87.35%
Oxygen (O_2)	12.5%
Carbon Dioxide (CO_2)	0.15%

Table 3.2.1.2. Agricultural Air Composition

dangers of its build up. CO_2 levels are also below the OSHA standards.

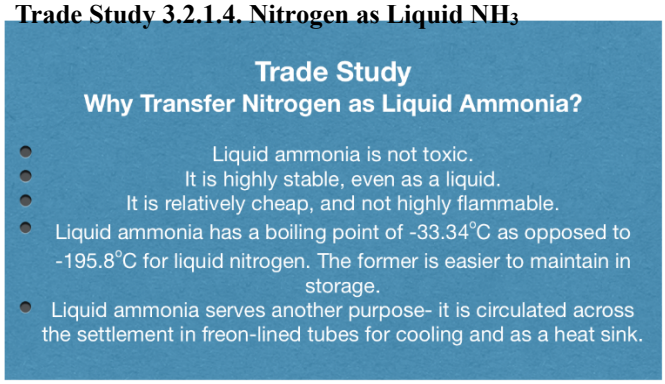
Construction Phase	Number of CASSSCs
Phase 1	460
Phase 2	845
Phase 3	3017
Phase 4	3216
Phase 5	237101
Phase 6	745
Phase 7	100

Table 3.2.1.3. Number of CASSSCs per Construction Phase

Nitrogen will be imported from Earth in the form of liquid ammonia. This will be separated; the hydrogen will be utilised to produce water via the Bosch reaction. It will be replenished by filtering urea present in urine. Nitrogen fixing bacteria in leguminous plants and denitrifying bacteria will also be used to maintain nitrogen level. This gas will be used for (a) help in maintaining consistent pressure levels, (b) help in human and plant growth, and (c) act as an inert gaseous buffer against undesired combustion.

Other gases, which include water vapour and a small amount of argon, need not be produced repeatedly because of Acasal water cycle and argon's inertness respectively. An initial supply of argon will be imported from Earth and maintained accordingly. Argon is mentioned for it is necessary for human metabolic processes and as an inert gas for metal pyrolysis. An inert gas also provides a safety margin for accidental pressure drops.

Trade Study 3.2.1.4. Nitrogen as Liquid NH_3



Filtration

The air filtration systems aboard Acasal must carry out two primary functions- the removal of CO_2 from the atmosphere and the filtration of other contaminants. While the former is facilitated by **amine hybrid silsesquioxane aerogel** (AHSA), the general filtration is carried out by **Hyper-HEPA** filters, which, by definition, filters particles down to 0.003 microns in size with a guaranteed efficiency of more than 99.5%. In hospitals, this will be used in addition to a thin layer of **cross-linked silica aerogel**, to provide further protection against microbes.

Scrubbing

CO_2, upon removal, must also undergo scrubbing, preferably by processes which yield useful products.

This is precisely what takes place on Acasal- CO_2 is used partly for, and partly for the Bosch reaction, with the primary scrubbing system being a **Biological Control System (BCS)** using spirulina algae, which also generates O_2. These algae tanks will be subjected to 640 nm and 700 nm light wavelengths via BIOS LED screens. The buffer stock of algae will be placed under natural light. Taking into account usual production rates, it can be deduced that one person would need 175L of algae culture. This implies a required volume of 1225 m^3, including buffer. Acasal will implement novel hydroxyl modified Polyamidoamine (PAMAM) dendrimer membranes. These have been shown to be extremely effective in CO2 scrubbing, with a CO2 / N2 selectivity of approximately 4000 and a CO2 permeability of 7e (-8) [ml cm/cm2 s cmHg].

Atmosphere Control

Temperature levels on Acasal will have a total range of 30°C, although these will vary slowly with time. Temperatures will be controlled by two methods. The first uses air conditioners that project air controlled by a **Proportional-Integral-Derivative (PID) thermostat** composed of sintered semiconductor material. Instead of a binary on/off method, PID control leads to the output of a certain value between 0 and 100%, leading to more precise temperature control. For the second method, integrated with the inner hull, a piping system controls the atmospheric temperatures. **Pure liquid ammonia** will be sent through this network of **freon-lined tubes** at variable rates to facilitate temperature control. This system will also serve the purpose of recycling heat, as the primary coolant pipeline will be covered by an **ammonia-cooled cupro-nickel heat sink**.

The necessary humidity conditions would be attained through **impeller humidifiers** and **molecular sieves** along with **electronic dehumidifiers with Peltier heat pumps** for increasing and decreasing the humidity respectively. Furthermore, **Condensing Heat Exchangers (CHX)** will remove moisture from Acasal atmosphere. The electronic dehumidifiers with Peltier heat pumps provide a cool surface for condensing water vapour. In case of the outbreak of

Trade Study 3.2.1.5. Agricultural Air Composition

Trade Study
LiOH Canisters vs BCS (CO_2 Scrubbing)

- Each Apollo mission carried approx. **thirty 4-kg** LiOH canisters for **3 astronauts** for less than **10 days** in space.
- This would scale up to about **26.4 metric tonnes** per day, which is clearly unacceptable, given Arial's estimated longevity.
- The BCS has algae that reproduce via fragmentation, sustaining their own numbers.
- They are also incorporated in the residents' diets in emergency situations.

a disease, humidity is **scaled down to 34-39%** in order to prevent the growth and proliferation of the causative microbe. A pressure difference between two points will be used to generate a breeze/ wind, by large vacuum pump systems installed in various parts of each torus in order to pump in or pump out the air in the torus based on the readings from the aneroid barometers, which ensures the value of P remains constant at all times.

Lighting and Day-Night Cycle

Acasal's day-night cycle will be similar to that of Earth, so as to prevent any inconveniences to the people in adapting to the new environment. One day would last 24 hours. In summers, the average daytime would be 14 hours and the winters will experience a 2.5 hour reduction to 11.5 hours. Life-like 3D projectors will be used to simulate an Earth-like sky on the outer surface of the shaft, which will vary with time and season. This light will only be secondary to the natural sunlight, which is captured from the cuboidal cavities (refer to section 2.3) within Principia and transferred to the residential areas.

In order to stimulate productivity in workspaces, additional light of **blue wavelengths** will be supplied to those areas, as light of shorter wavelengths is known to suppress excess melatonin levels, i.e. helps workers stay active and awake during the day.

Table 3.2.1.6. Seasonal Variations

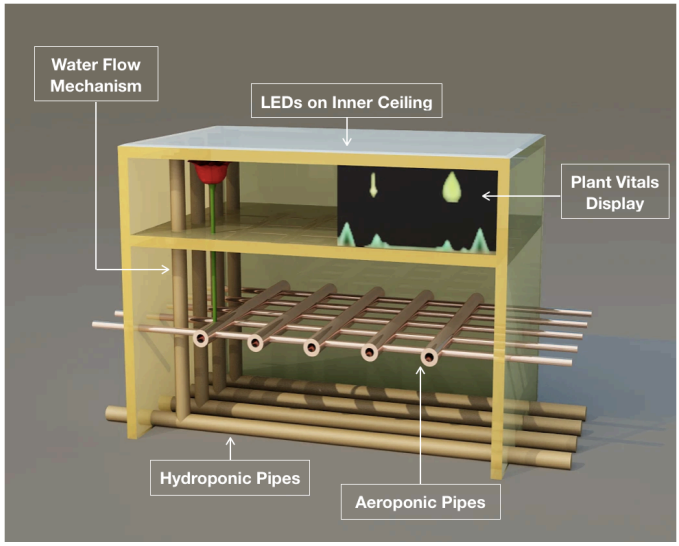
Season	Temperature	Humidity
Summer	24°C - 36°C	30% - 33%
Rainy	25°C - 29°C	50% - 65%
Winter	5°C - 21°C	24% - 27%
Spring / Autumn	17°C - 25°C	31% - 36%

3.2.2. Food

Agriculture

Acasal employs a modular agriculture system based on a composite of hydroponics and aeroponics. The system consists of multiple **CERA** (Controlled Environment Regenerative Agriculture) units built around modular grids, which may connect to other such units in order to utilise, to the maximum capacity, the available space. This modularity also implies that the required aeroponic and hydroponic nutrient solutions need only be pumped into each modular 'farm' from but one source and entry point, and these are transferred across all units. Moreover, since individual units can be closed off, it is easy to prevent the spread of pests or diseases, as the faulty system may simply be closed off, acting as simply a relay unit for the nutrient solutions. Aeroponics is used for adult plants, and hydroponics is used on a limited scale, for the saplings, which have rather delicate roots and require constant and direct exposure to water. This system is estimated to reduce water consumption by 98% and vastly improve growth efficiency.

Figure 3.2.2.1. Agriculture- CERA



Agricultural System

As per the figure, each CERA unit contains an aeroponic layer and a hydroponic layer, with the former constituting most of the unit. Adult plant roots are connected to tubes from the aeroponic grid while sapling roots are submerged in the hydroponic grid. The shoot-systems are separated from this layer and covered from above by glass panes. Here, they are exposed to the optimum range of wavelengths for general plant growth, dominated by blue light (**430nm-450nm**), which will be provided in larger amounts for saplings, as it encourages vegetative growth and red light (**640nm-680nm**), in particular the **660nm** wavelength, which facilitates stem growth, flowering and fruit production, and chlorophyll. Sprayers and pores embedded in the side walls will maintain the air in each grid, providing a suitable atmosphere for the plants. When the sensors in a unit determine that the plants are ready for harvest, they are cut at the bases by retractable blades and are pushed into the plant collector, which carries them out of the unit.

CERA units will be present in cylinders at different g-levels so as to provide opportunities for research on plant growth in varying gravitational conditions.

Non-Agricultural Food

Keeping livestock aboard the settlement is not an option, given the enormous quantities of resources they consume in terms of space, food, etc. To avoid this, or regular imports from Earth, meat is grown aboard the settlement from an initial stock of tissue cells. The elimination of a trophic level from the food chain will also move humans one step closer to primary productivity and increase the effective yield of energy input tenfold. These cultured masses may also be ordered by residents for customised meals, provided for by 3-D printers in the residents' houses.

Milk: Since there will be no livestock aboard Acasal, suitable replacements for dairy products must be used. For milk, yeast will be transferred from Earth along with samples of cow DNA, out of which certain sequences will be inserted into the yeast cells. These are then grown in appropriate conditions for a few days, after which milk proteins are obtained. Fats from vegetables and minerals like calcium and potassium, and sugars are separately added to the mix to form the final product. This process uses 98% less water and 91% less land. There exist alternative milk options, however they have a very high-water usage. This milk is lactose-free too, thus catering to a larger section of the population.

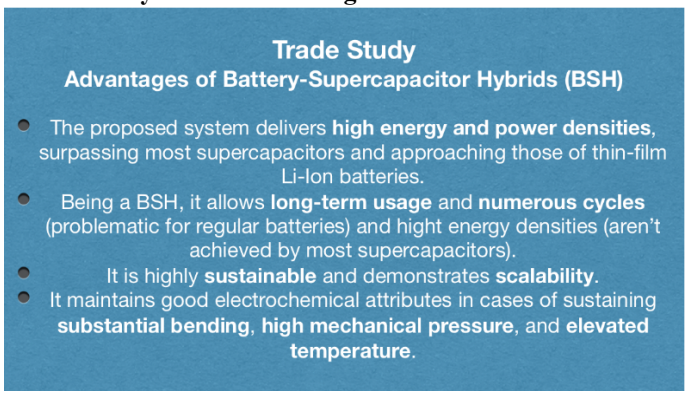
Eggs: Eggs and egg products will be synthesised from mixtures of peas, sunflower lecithin, canola, and natural gums, along with certain other plants and covered by edible carbonate shells. The eggs produced in this process are gluten and cholesterol-free, allowing larger sections of residents to consume them.

Packaging and Delivery

Crops will be stored in clean, dry and **isolated (low-oxygen) cryogenic silos**. Meat products and fruits will be stored in blast freezers which will be set to a temperature of -70◦C to ensure proper storage. Food rotation will be utilised to preserve freshness, i.e. the food which has been in the storage containers for the longest period of time will be consumed first. Bridgmanization and food fortification will be used for sterilizing the food. In this, high pressure (70000 psi or greater) leads to the inactivation of certain microorganisms, yeast, bacteria and enzymes. Foodstuffs for retail and/or direct consumption (excluding liquids) will be packaged in **carbon nanotube (CNT) reinforced polymer nanoclay films**, owing to their favourable mechanical characteristics as well potential antimicrobial characteristics. These work well for solid foods, but for liquids and raw pastes (like those used for 3-D printing), the CNTs will be replaced by **Cellulose Nano-Reinforcements (CNRs)**.

People will be able to obtain edible food by 3-D printing and by cooking on **induction cooktops** or **forced air convection ovens**.

Trade Study 3.2.3.1. Advantages of BSH



3.2.3. Power Generation

Power requirements for the settlement are met through solar panels, the combustion of methane from organic waste processing, as well as general day-to-day activities, depending on the conversion of kinetic or heat energy to electrical energy.

Acasal's energy needs are primarily met through solar energy, using **multijunction solar cells on GaSb substrates**, with a spectral response range covering the region containing more than 99% of the available direct−beam power from the Sun. The chosen design is estimated to provide an efficiency of 44.5%. The top and the bottom solar panels each have a layer of **electrochromic glass**. A surge of electricity changes it from completely transparent to reflective hence facilitating easy maintenance of the engineering components the day-night cycle. Panels are made dormant and active according to power requirement. When sunlight is required, it becomes transparent. The panels are coated with **ARC** (anti-reflective coating) in order to increase efficiency.

Table 3.2.3.2. Power Distribution

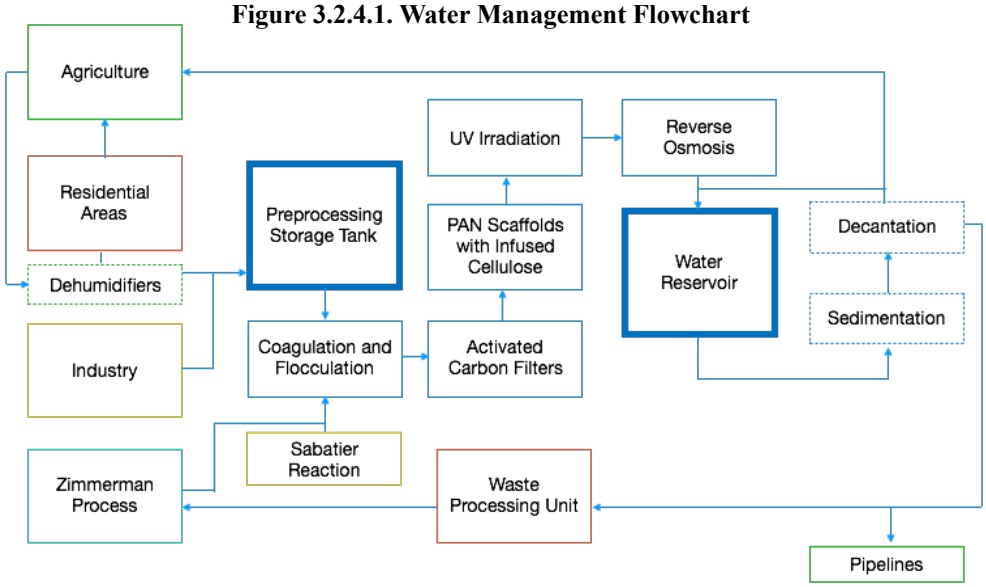
Sector	Requirement (kWh / day)
Residential	85,000
Atmosphere Control	1,20,000
Water Management	45,000
Automation	1,52,000
Agriculture	7,000
Backup	1,63,000
Industrial	2,40,000
Total	8,12,000

Acasal will also employ the **Bosch process**, whereby carbon dioxide and hydrogen yield water and graphite. For the initial reactions, hydrogen will be imported, and these will be sustained by a closed loop process, with hydrogen being obtained again by electrolysis of water.

Energy will be stored using a lithium-ion base for a **solid state rechargeable alkaline**

battery-supercapacitor hybrid paired with capacitive **carbon nanotube (CNT) film cathodes**. The advantages of this system are underlined in the trade study. When these aren't available, an alternative supply of nickel-hydrogen batteries will be used.

Figure 3.2.4.1. Water Management Flowchart



3.2.4. Water Management

Water from chemical processes like the Bosch reaction, from manufacturing areas, dehumidifiers, and the waste management unit will be transferred to the water processing unit, after separating it from the solids it was associated with. Here, it will be subjected to a number of processes for treatment:

The impure water initially undergoes **coagulation** and **flocculation**, which will separate the heavier and denser impurities like solid faeces and immiscible liquids from water.

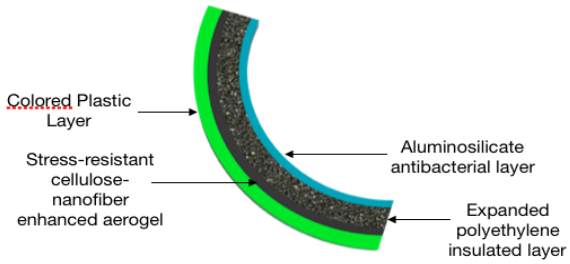


Figure 3.2.4.3. Water Tank Cross-Section

Following this, it undergoes filtration in two stages. First, it is subjected to filtration by **activated carbon** (which is also processed from the carbon obtained from the Bosch reaction), which adjusts the pH balance of the water and removes a number of contaminants. The second stage of the filtration process involves passing the water through **two-layered Nano-scale polyacrylonitrile (PAN) scaffolds** containing infused ultra-fine functional cellulose Nano-fibres. This membrane is capable of removing bacteria, viruses, or toxic heavy metal ions. This upper layer would contain a substantial number of negatively charged amine groups on the ultrafine cellulose nanofibers- an arrangement, which has seen the complete removal of bacteria (E. Coli). This is followed by **UV irradiation**. **Reverse osmosis** will ensure the complete removal of ammonia from the water. This ammonia may either directly be used for nitrogen generation (if required) or may be delivered for circulation around the settlement, and thus, temperature management.

Table 3.2.4.2. Water Distribution

Requirement	Quantity (L/day)
Residential	3,25,150
Industrial	2,32,500
Backup	2,55,750
Agriculture	70,000
Total	8,83,400

To conserve water, clothes will be cleaned and dried using **air washing**, and traditional bathing methods will be replaced by special gels containing bioflavonoids and natural emollients for cleansing the skin, while preventing dryness, irritation and body odour. Moreover, firefighting will use **monoammonium phosphate** instead of water.

This not only reduces water usage, but also enables proper fire extinguishing for breakouts caused by electrical appliances and requires less cleaning afterwards. Although in case of failure or any other complications by the extinguisher some amount of water will also be available as backup.

An initial quantity of water, inclusive of an acceptable buffer, will be imported straight from Earth before the residents occupy the settlement. The water will be stored in tanks with a layered design, as in the given figure.

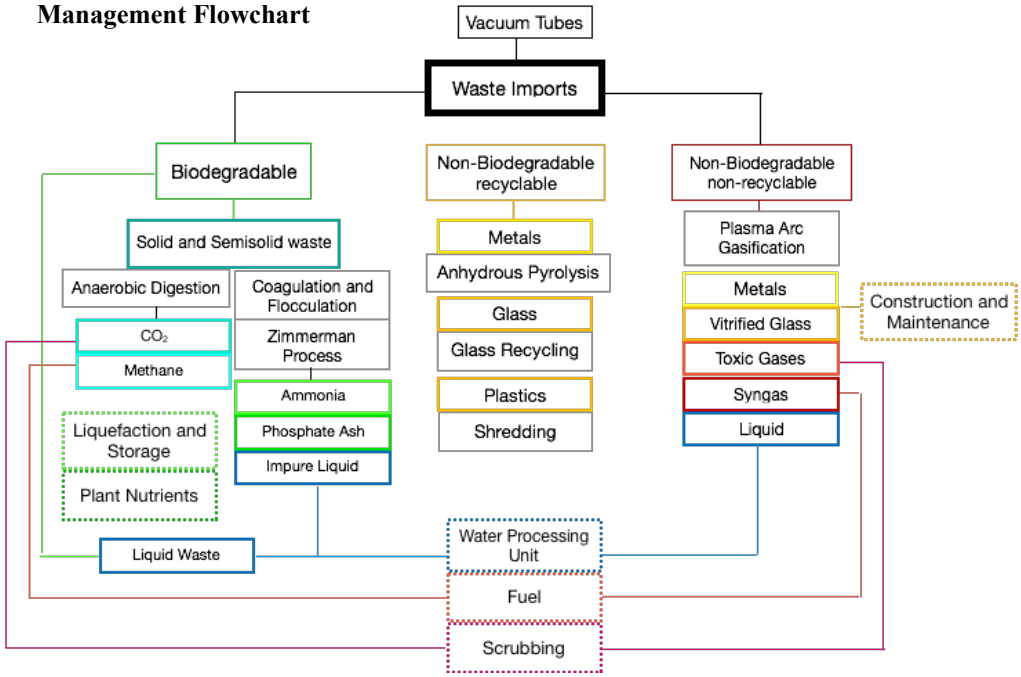
Table 3.2.5.1. Waste Management

Waste Category	Quantity (kg/day)
Biodegradable	11,900
Non-biodegradable	2,560
Total	14,460

3.2.5. Waste Management

Waste is directed from different parts of the settlement to the processing units via **vacuum tubes.** There are two separate channels for waste transport- one for biodegradable waste and one for non-biodegradable waste. Matter from the former is processed at once, while the latter first undergoes sorting. The non-biodegradable waste management system is based on **single-stream recycling**, wherein all the waste is first collectively transferred to the processing units, after which it undergoes **induction sorting**. Finally, the non-biodegradable waste is separated into recyclable and non-recyclable components.

Figure 3.2.5.2. Waste Management Flowchart



Initially, the biological waste would be separated into solid and liquid phases by **accelerated sedimentation**, which would be achieved through loading via charged particles in a tank with an oppositely charged bottom, whereby the liquid waste would be left to enter a separate route. Water will be separated from the remnant waste through **vapor distillation** and sent to the water processing unit..

Further separation would be achieved using **trommel separators**. A portion of the organic liquid waste would be transferred to processing units where **anaerobic bacteria** (acetogens and methanogens) would convert wastewater into methane, which would be used in energy production and carbon dioxide, which would either be let out into the atmosphere or transferred to the agricultural sectors based on the needs of the moment. These processing units would be modified for anaerobic digestion. The remaining liquid waste first would be subjected to **coagulation**, and thus, **flocculation** by polyamine and polyDAMAC coagulants. Thereafter, it would undergo the **Zimmerman process,** resulting in ammonia and phosphate ash, the former of which would either be liquefied for storage or broken down for nutrient supplies in agriculture. The ash would be used as a source for plant nutrients.

The recyclable non-biodegradable waste will be separated into its constituents (glass, metals, plastic). These are then recycled separately. First, the plastics are shredded, after which they undergo **anhydrous pyrolysis**, by which the plastic waste is completely treated. These may then either be directly recast into usable forms or stored for later usage in 3D printing. The metals, too, undergo pyrolysis, whereby they are **thermally cleaned**, and thus, rid of organic substances such as polymers, plastics and coatings. They are then further melted and recast into new forms. Glass undergoes recycling by similar processes. The remaining non-recyclable non-biodegradable waste undergoes **plasma arc gasification**, instead of traditional incineration. This is because plasma gasification prevents metal particles from evaporating, where the presence of O2 would lead to metal oxides, which would hamper the process. The initial usage of plasma torches would separate vitrified glass and several metals from the waste. The toxic gases generated in the process would be transferred to adjoining areas where intensive scrubbing would take place. While the required temperatures may be high, necessitating large amounts of energy, the combustion of the syngas yields enough energy to make the process self-sufficient.

The liquids remaining after these processes are transferred to the water processing centre, wherein they are purified, and made fit for consumption.

3.2.6 Internal and External Communication

Internal Communication
In Acasal, internal communication will mainly be carried out via **Zinc Selenide Fibre Optics**, thus allowing the capability of transmitting even heavy data at a rate of 1 TB/s. This 50/125 optical fibre

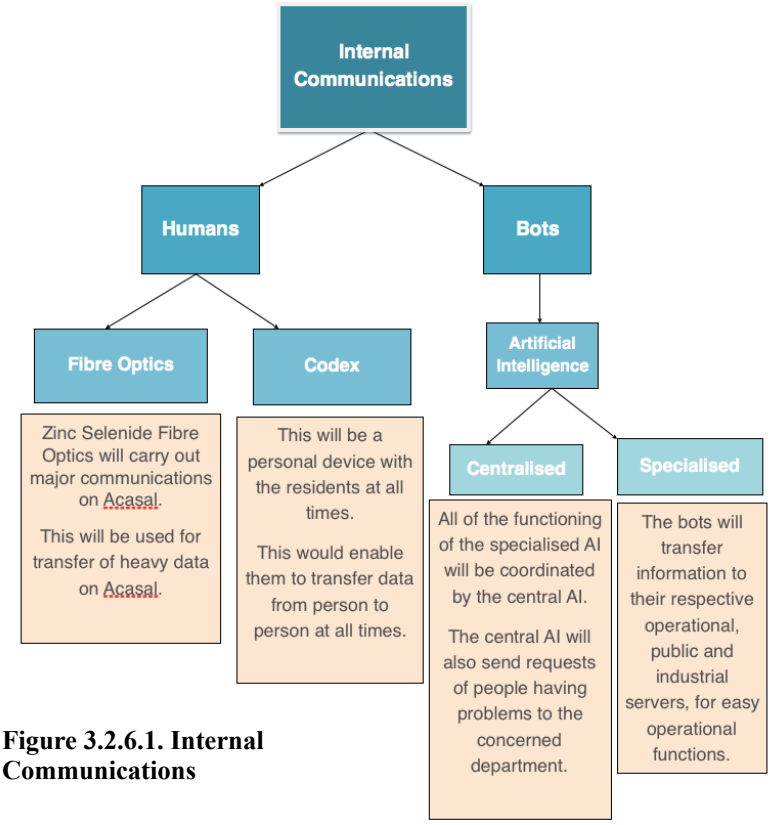


Figure 3.2.6.1. Internal Communications

will have a bandwidth of 400-500 MHz.km.

Codex (refer to section 5.3) provides person-to-person communication. To connect Codex units with each other, **WiMAX** will used. WiMAX provides a network in the settlement for transferring data at high speed of 84 Mbps among the people and has a frequency of 2 GHz to 11 GHz.

While methods like LiFi were considered, they were found to be unsuitable for the settlement, as such signals suffer from the interruptions Acasal's structure is likely to present.

External Communication
Acasal will primarily employ **Reconfigurable Wideband Ground Receivers (RWGRs)** paired with **bi-directional laser communication** through satellites for its external communications:

- Antennae are present on the exterior of the settlement, and are used for transmission.
- These antennae transfer and emit laser wavelengths ranging from 10^{-5} to to^{-4} metres. These smaller wavelengths allow data to be transmitted across narrower beams, and increase security as well as intensity.
- Moreover, they are placed away from areas with human access, as the radiation may affect humans.
- For receiving purposes, Acasal uses Reconfigurable Wideband Ground Receivers (RWGRs). These are reprogrammable receivers with variable data rates.
  - An RWGR has a software-defined radio receiver using an Intermediate Frequency (IF) sampling receiver that operates at a fixed sampling rate of 1.28 GHz with a 500 MHz instantaneous receive bandwidth.
  - The RWGR's yield performance is close the theory in terms of BER(Bit Error Rate) with losses typically less than 1 dB in bit signal-to-noise ratio (SNR).
  - Acasal will ultimately provide telemetry data rates in excess of 1 Gb/s using this system.
  - To help optimize performance, the settlement uses ICER image compression as opposed to standard JPEG compression, as it achieves the same results using less complex and power-heavy systems.
  - The laser systems will be encoded with encryption and decryption programmes for outgoing and incoming messages respectively, to ensure the data isn't externally compromised.

3.2.7 Internal Transportation

Acasal's internal transportation can be classified into– domestic, public, and emergency transportation.

(a) Personal transportation- A bicycle track will be built all along the residential cylinder. Eco-friendly bicycles and Segway will be used. Along the height of the cylinder a track 1 m wide will exist in *Singularity.*

- ***Hermes*** (Bicycle) will be powered with batteries which ranges up to 50 km and have a speed of 20 km/h. Initially the paddles are folded but, in case of emergency, the paddles unfold and come at its initial position, so that the user can paddle up to move on. The bicycles may also fold, in order to fit into compact spaces, increasing overall storage

capabilities. A part of the kinetic energy generated during bicycle use is converted to electrical energy and stored in small batteries attached to the bicycles.

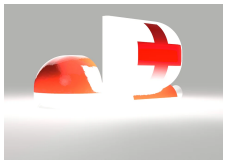
Name	Dimensions	Image	Quantity
Hermes (bicycle)	Height: 1750mm Length: 980mm		2000
Mercury (Segway)	Height: 457mm Wheel diameter: 260mm Length: 420mm		1400
Apollo (Transit Elevated Bus)	Ground displacement:3m Height of compartment: 4.3m Length: 12m Width: 2.5m		280
Medical Bot ***odysseus***	Height: 2m Length: 4m Breath: 1.5m		400

Table 3.2.7.1. Modes of Transportation

- ***Mercury*** (Segway) will be powered with batteries which ranges up to 25 km and have a speed of 15 km/h. It can be carried anywhere and can be controlled with a remote which everything about the Segway.

(b) Public Transportations is used to the transport residents to their respective places of work, other residential cylinder, the central shaft, etc. A transit elevated bus system will be used for this purpose. The bicycle track under the bus system, hence conserving a large volume of space.

(c) In case of emergency, ***Odysseus*** the medical bot, the only vehicle apart from bicycles to be allowed on the bicycle track, will be available to transport people to the transport people to the hospitals. Apart from these, the elevators present within central shaft channels are pressurized, so that people could move from one cylinder to the other.

3.3 Construction Machinery

Internal Construction

Selective Laser Sintering (SLS) from nano bots and 3D printing will be used by Pygmy bot (refer to 5.1) for interior construction of Acasal. Selective Laser Sintering uses laser to completely melt layers of products rapidly and precisely.

Table 3.3.1. Construction Robots

Robots	Methods	Functions
Pygmy bot	3D printing	Building internal layers of the settlement
Nanobot	Selective Laser Sintering(SLS)	Airtight seals on the internal structure
Porphyrion	Contour Crafting	Building outer structure of the settlement
Inspection bot	MEMS (Micro-Electro-Mechanical Systems)	Hull inspection for exterior structural components

External Construction

For construction of the external structure, Porphyrion will lay down jigs with the help of nano bots (refer to section 5.1.). This system has been adopted for efficient and systematic movement of bots for construction in 0g. The jig gets attached to the hull which supports its movement***(refer to fig. 5.)***

Both Pygmy and Porphyrion will be provided with materials in table 3.3.3.

3.4 Station Keeping

Acasal is present in a halo orbit around the L1 libration point. By nature, this orbit is dynamically unstable; even a small displacement from the equilibrium motion will grow exponentially. This

Process	Description	Advantages	Uses
Selective laser sintering	It is an additive manufacturing technique that uses a laser as the power source to sinter powdered material, aiming the laser automatically at points in space binding the material together to create a solid structure.	Parts possess high strength and stiffness Can make unique parts in a short period of time. Good chemical resistance. Does not require special tooling. Complex parts with interior components, channels, can be built without trapping the material inside and altering the surface from support removal	3d printing and manufacturing
Flash welding	It is a type of resistance welding that does not use any filler metals.The pieces of metal to be welded are set apart and are connected to a transformer. Current is applied to the touching points which rapidly heats and melts the metal. This creates resistance and melts and heats the metal rapidly. Once the pieces of metal reach the proper temperature, they are pressed together, effectively forge welding them together.	Uses cheap and easily available material. Only uses heat or force.	Welding
Magnetic Pulse Welding	Repulsive forces and a high magnetic pressure is created between 2 work pieces beyond the material yield strength causing collision with high velocities.	It can be carried out in vacuum Does not require molten metal Almost zero residual stresses No Distortion. No need for filler materials.	Welding

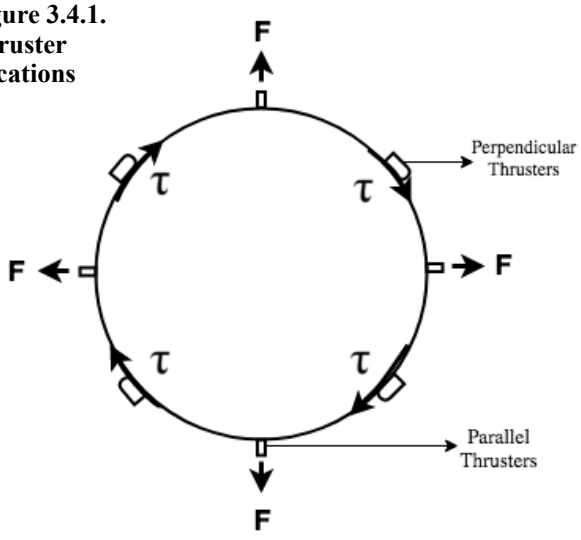
Table 3.3.2. Methods of Construction

necessitates the usage of a propulsion system for station-keeping.

The thrusters are placed on the exterior of the *Singularity* and *Hubble*, 4 perpendicular to the radius of the cylinder, maintaining rotation, and 4 parallel to it, maintaining position of the settlement, each one equidistant from each other.

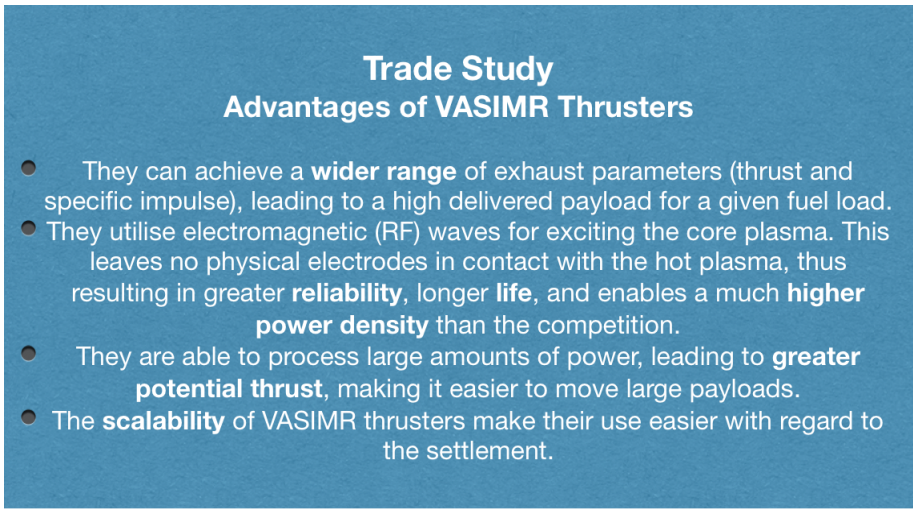
Acasal will employ Variable Specific Impulse Magnetoplasma Rocket (VASIMR) thrusters, instead of other types, such as Vernier thrusters. This variety provides many unique advantages, given its mechanism, wherein xenon, or hydrogen is injected into a tube placed in a magnetic field and RF couplers. The couplers superheat cold gas to plasma and the magnetic nozzle converts the

Figure 3.4.1. Thruster Locations



releases the plasma in a directed jet. For Acasal's purposes, xenon (Xn) gas will be used as fuel. Xenon was chosen due to its inert nature and superior density, as compared to other noble gases.

Trade Study 3.4.2. Advantages of VASIMR



This density allows a higher impulse per unit volume too.

These thrusters will facilitate station-keeping using a discrete-time sliding mode control (DSMC) approach. The process of parameter tuning is easier using DSMC, and unlike other methods, it poses a lower risk of inserting the settlement into unstable manifolds of the nominal orbit. This also provides a lower average position deviation (less than 20 km).

The average yearly delta-v required for the settlement is estimated to be 60 m/s. The final required fuel mass turns out to be 72 grams per second, with storage units located by the thrusters, as specified in figure 3.4.1.

3.5 Docking Operations

3.5.1 Location

Acasal will accommodate minimum four visiting ships and would expand to much beyond four after whole settlement is made. Each port has a volume of 98214.28 m^3, allowing ample room for large spacecrafts, transport and storage of goods.

Before Initial Operating Capacity (IOC) is achieved in phase 3, we will have 8 docking ports operating by phase 2, all of which are attached with airlocks and a storage module, located on the semi-circular prism component of *Principia*. These docking ports receive passengers and cargo. Besides all these, there is one dock available as backup which will conditionally become operational when required.

3.5.2 Accommodation of ports

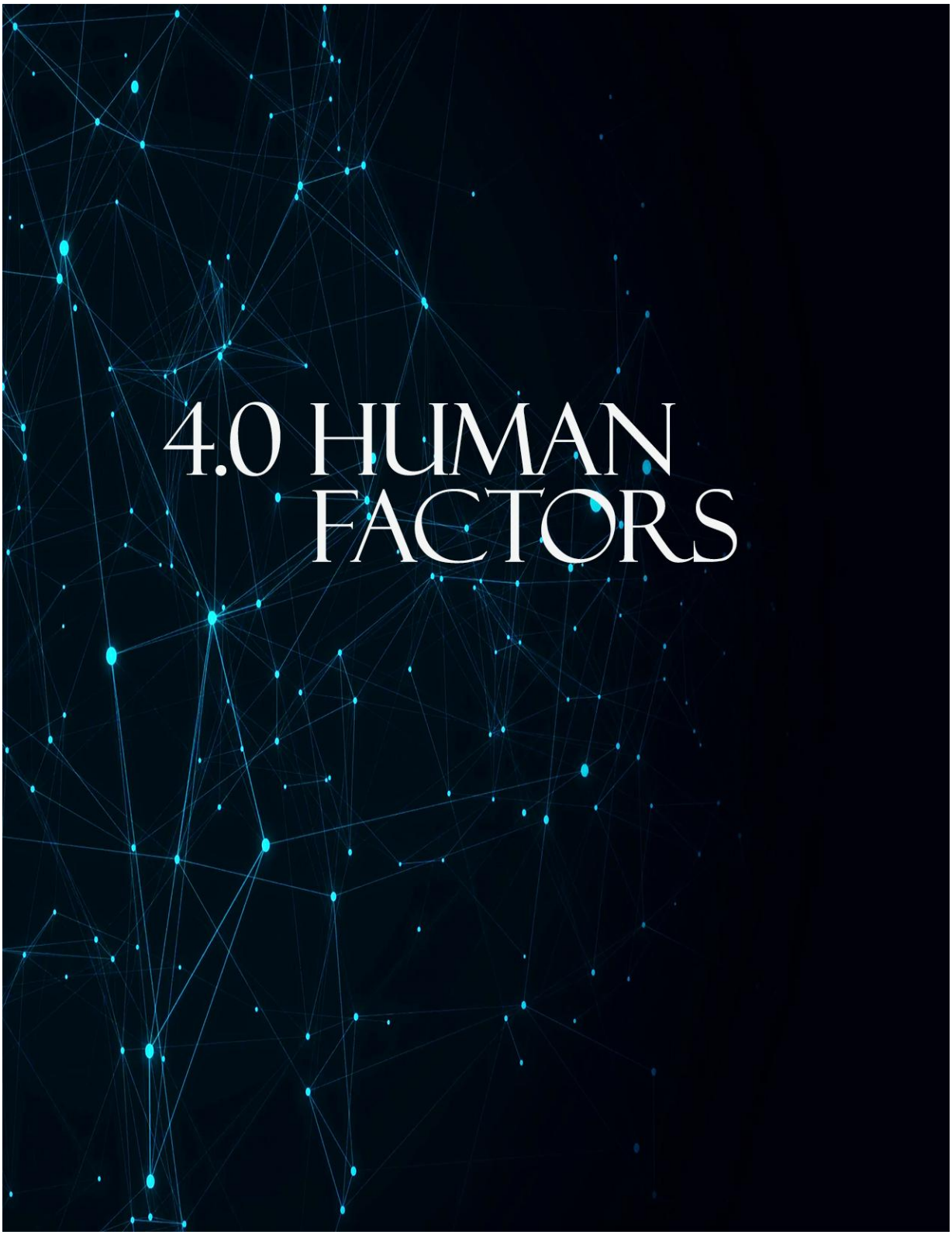
Acasal has ports for the transportation of the people only, from any other location to the settlement. As for the passenger ship, a larger airlock is used when they board on Acasal. There is a central transportation system, further *elaborated in section 7.1.*

For the docking of the ships, a platform extends out of the docks; the ship is then attached to this platform and extendable platform then comes back in, taking the ship along with it.

All cargo is stored in CASSSCs are taken out of ship through REX (loading/unloading bot) and loaded on LEX (0g transportation bot), this bot will proceed to a decontamination chamber where examinations will be conducted by nanobots to check for any damage/excess dust. The CASSSCs will then be transported to the storage module.

All docking areas are also equipped with a series of articulating arms for the purpose of resupplying ships with fuels. The use of these extendable arms, and adaptations provides the highest quality in resupply services which will operate as a highly efficient fuelling pump in space

For Repairs, a Pygmy will be present in each dock. Pygmy would be able to 3D print and repair the bot and ship easily.


4.0 HUMAN
FACTORS

4. Human Factors: Acasal offers its residents attributes of a small city on Earth through its residential designs, interiors, activities and recreation – while considering implicit requirements and required safety systems. By virtue of its structural design, residential models in Acasal provides both natural and artificial sunlight and views of Earth below and Luna above, through alternate windows (fig 4.1) and an observatory located in principia equipped with an infrared telescope and virtual reality earth tours along with a sunlight funnelling mechanism that channels sunlight towards *singularity*.

4.1 Community Design

4.1.1 Services: Acasal provides a wide range of facilities to its residents through three lifestyle designs – traditional, modern and chic.

Health	Education	Parks	Entertainment	Recreation
Most houses are situated in Singularity (1g) to facilitate bone development. Houses situated in Chirals (less than 1g) have electricity-producing gym equipment for cardio exercises.	Singularity houses the Acasal Elementary School which offers online learning lectures in affiliation with institutions on Earth and grants recognized diplomas. It also houses a Library and a Museum to facilitate learning.	All residential locations in Acasal are spacious and adequately supplied with parks. Half of the edges of Singularity are covered with green belts.	Singularity houses a mall, a multiplex, a stadium for regular sports and a theater.	Three Chiral floors host activities as elaborated in Section 4.4.

4.1.2 Consumables: Acasal provides a wide variety of consumables including food, medication, electronics, toiletries, etc.

S. No.	Food Item	Nutrient Content	Amount per person per year (kg)	Total amount per year (kg)
1	Dairy	Calcium, potassium, protein	351	2316600
2	Egg	Protein, riboflavin, selenium	146	963600
3	Cereals	Fiber, vitamins, omega 3 fatty acids	36.5	240900
4	Nuts	Fiber, vitamins B, E, calcium, zinc	10.22	67452
5	Soy	Fiber, iron, magnesium, protein	9.2	60720
6	Beans	Vitamin B6, pantothenic acid	9.2	60720
7	Broccoli	Fiber, vitamin B6, pantothenic acid	20	132000
8	Cabbage	Manganese, fiber, vitamin C, B1	14.6	96360
9	Okra	Protein, riboflavin, niacin, zinc	9	59400
10	Other vegetables	-	55	363000
11	Citrus fruits	Vitamin C, fiber, potassium, folate	29.2	192720
12	Other fruits	-	115	759000
13	Fish	Omega 3 fatty acid, Vitamin D, B2, calcium	15	99000
14	Pulses	iron, potassium, magnesium, zinc	22	145200
15	Pork	Thiamin, zinc, vitamin B12, B6, niacin	22	145200
16	Other meat	-	44	290400
17	Wheat	Carbohydrates, Protein, Vitamins and Minerals	9	59400
18	Corn products	Fiber, phosphorus, vitamin C, magnesium	7.2	47520
19	Rice	carbohydrate, protein, fat	18.2	120120
20	Processed food	-	30	198000

4.1.3 Community Design: While houses are kept compact, all residential units are spacious and facilitated with ample parks and green covers. Maximum houses in Acasal are provided in 1g to facilitate healthy growth. Since low g makes movement easier, people burn fewer calories. Hence every house located in low g is equipped with a gym with basic equipment for cardio exercises. Gyms are facilitated with the electricity- generating equipment. Residents will enjoy long lines of sight as instead of coaxial cylinders , chirals have been used (refer section 2.1 , salient feature 5)

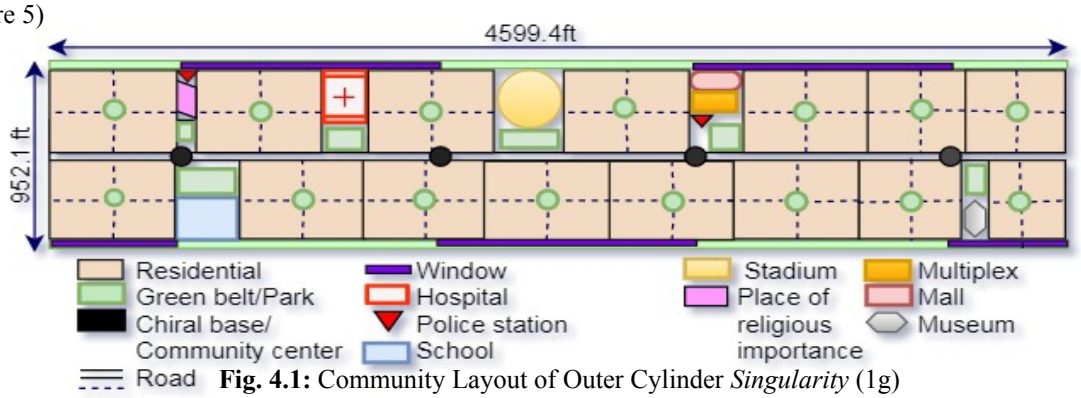


Fig. 4.1: Community Layout of Outer Cylinder *Singularity* (1g)

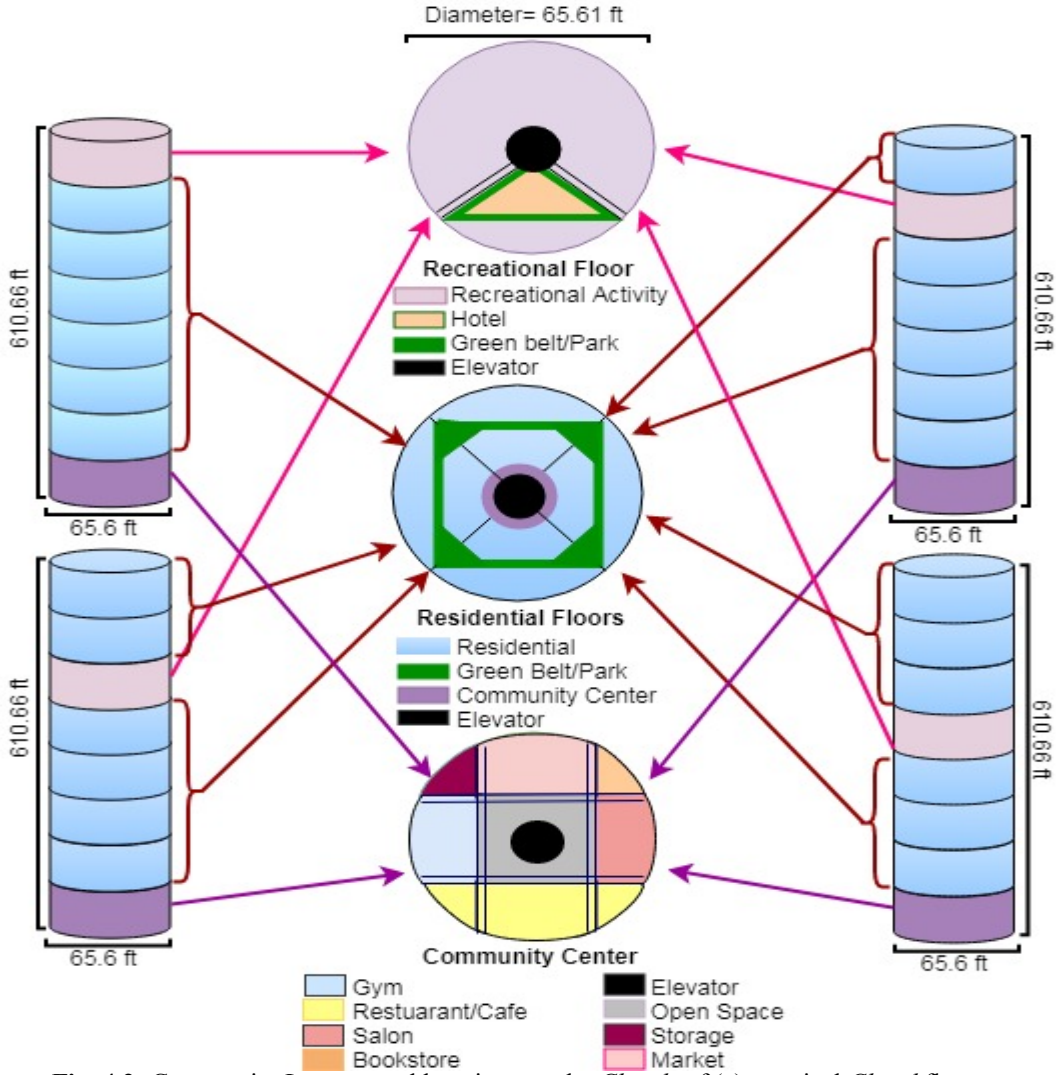


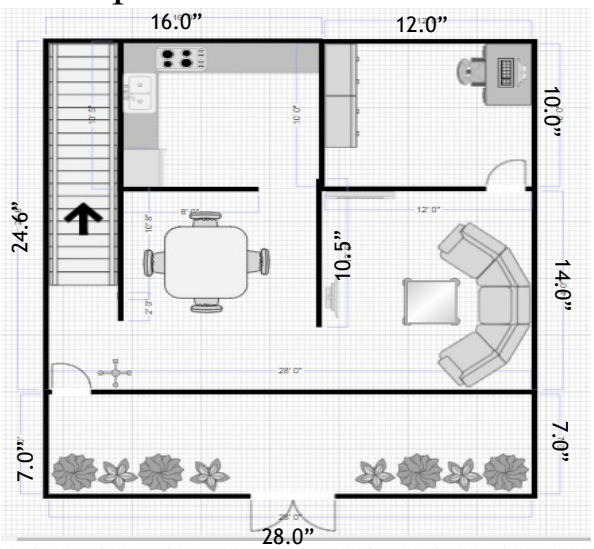
Fig. 4.2: Community Layouts and locations on the *Chirals* of (a) a typical *Chiral* floor hosting permanent residents, (b) a typical *Chiral* floor hosting activities, in-transit residents and permanent residents, and (c) Community Centers located on the *Chiral* bases.

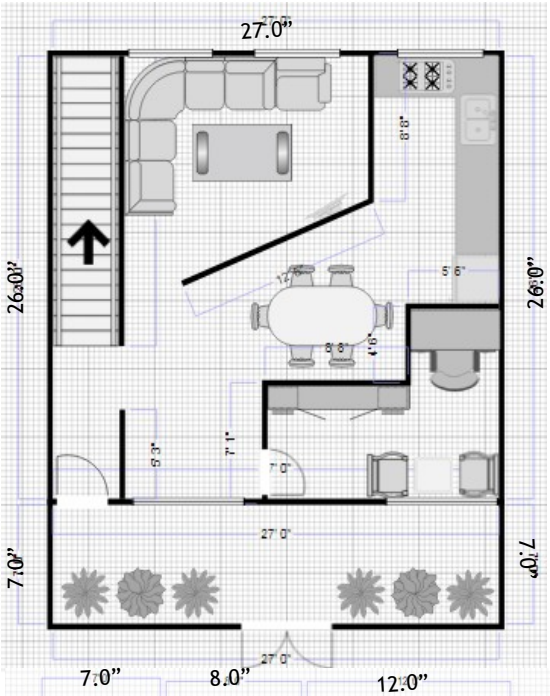
4.2 Residential Design: Acasal provides three types of housing designs – Traditional, Modern and Contemporary – each varying in its architecture to suit all types of lifestyles. We have repurposed CASSCs for housing accommodation. Houses will have led windows which will allow residents to customise their views"

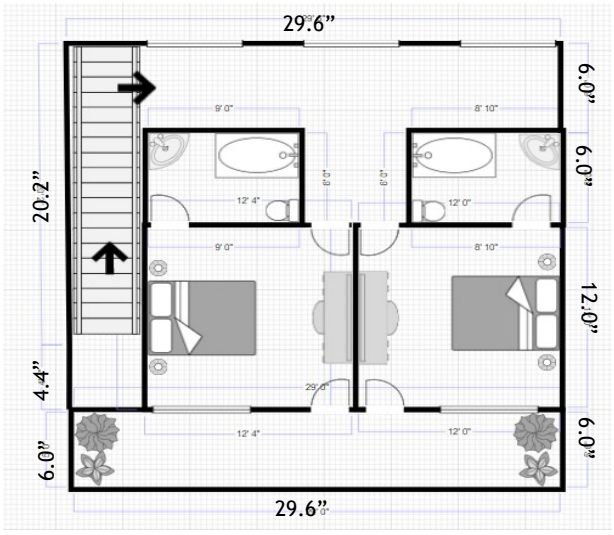
Traditional Housing: Essentially designed for family life. Located in adequate g regions, hence do not have personal gyms. (Open gyms are provided in parks) Affordable houses with well-utilized space. This region facilitates cultured growth of children by providing Earth-like environm

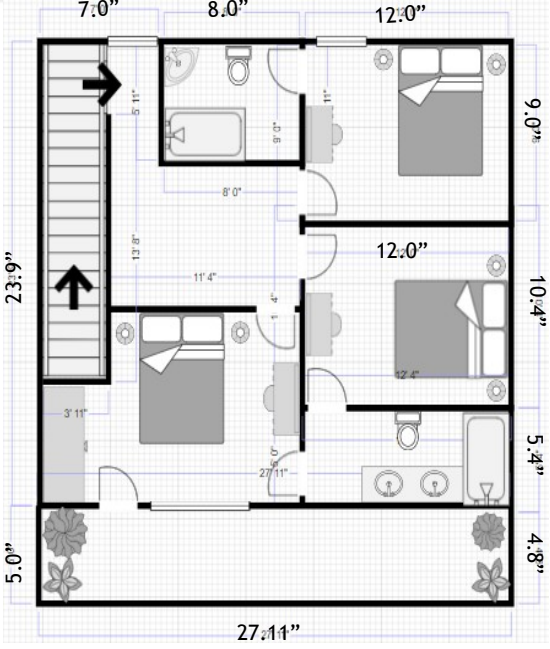
Traditional Large (3BHK – Duplex

Traditional small(2BHK – Duplex) 870sqft





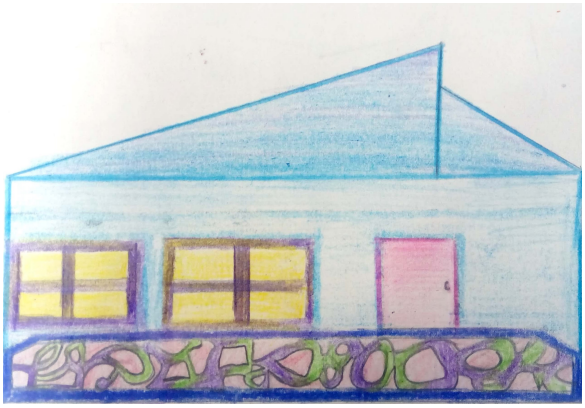


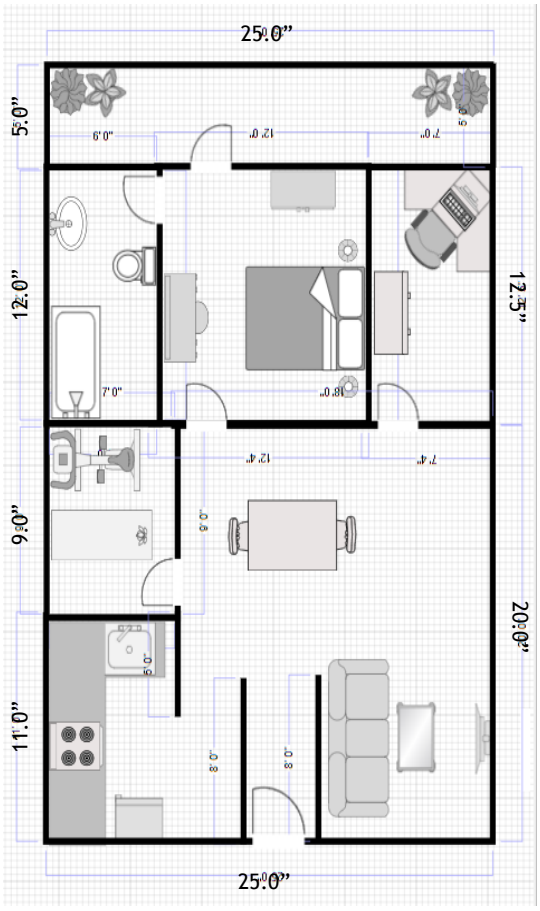


- **Modern Housing**: Essentially designed for young adults and transient visitors. Located in minimum g region since most residents are temporary. These minimalist houses with chic interior facilitate economic living.

Modern Small (1BHK)

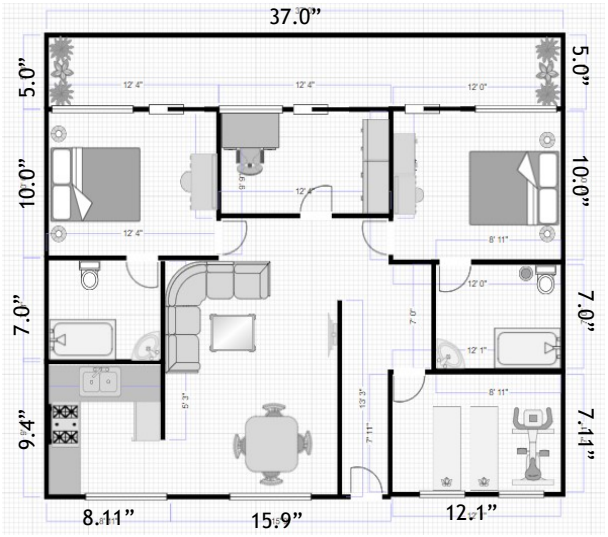
925 sq ft



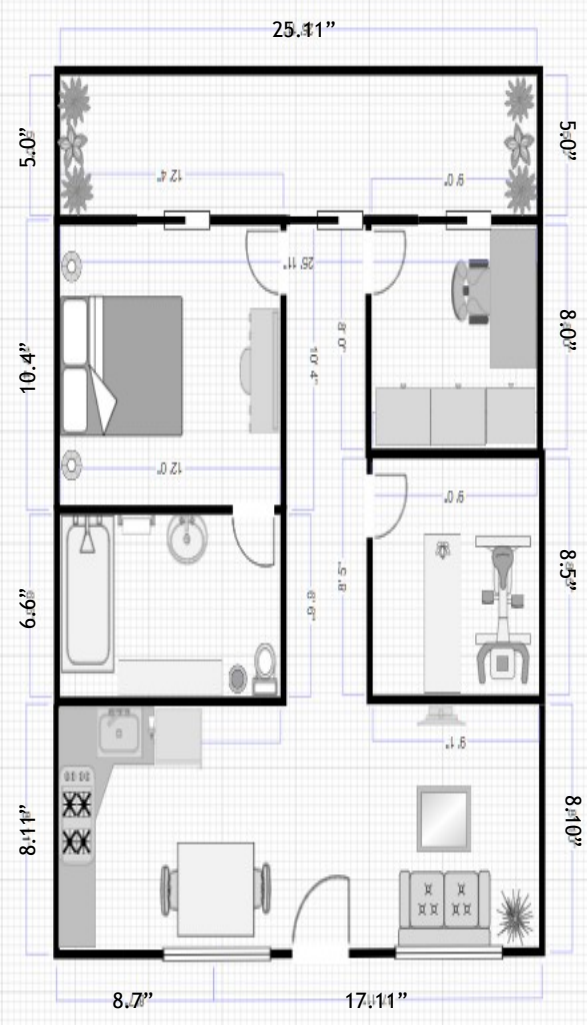


Modern Large (2BHK)

1180 sq ft



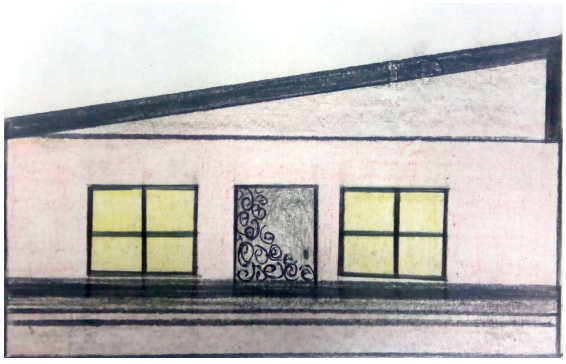
Contemporary Small (1BHK) 780 sq ft

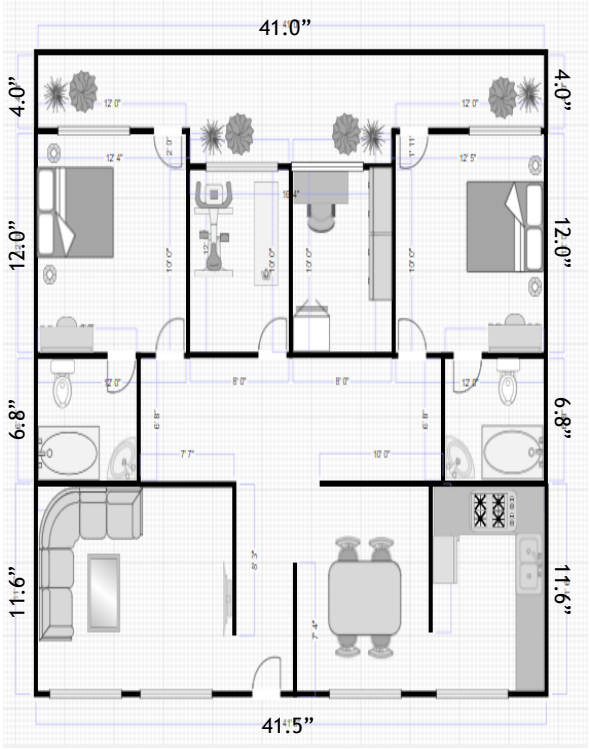


Contemporary Large

(2BHK)

1400 sq ft





4.3 Safety features

4.3.1 System devices vehicles

Systems and devices have been adequately designed to help movement in low g and unpressurized areas. There will be cameras and motion sensors to monitor the humans in the zero-g and micro-g areas. These cameras will report danger if there is any harm caused to the humans. They are as following: -

Padded walls

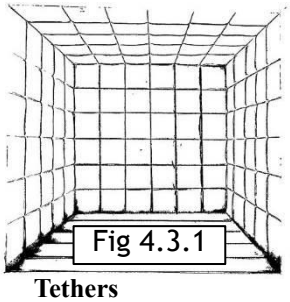


Fig 4.3.1

Walls and roofs will be padded to prevent injury made using memory/temper foam as it evenly distributes pressure and weight countering the pressure with an equal pressure

Tethers

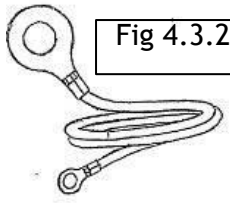
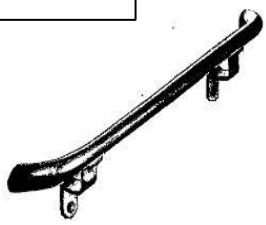


Fig 4.3.2

Tethers will be made using lunar silicon (Bucky structure) for flexibility and high tensile strength. They will be retractable and up to 10 meter long

Fig 4.3.3



Handrails will be made from Iron-nickel-aluminium alloy which make them cheap and durable. They will be 1 meter long

3.2 Spacesuits –

The main extra vehicular activity performed will consist of surface expeditions and settlement- tethered human trips when human surveillance/assistance is needed. For these, personnel will use spacesuits which will be provided on surface exploration vehicles and spacesuit stowage areas on the settlement. Spacesuits will also be present in the contingency pods . The following will be the features of the spacesuit-

•Outer most layer made using modified Bucky structure fabric and Kevlar to prevent damaged by space debris.

•Middle layer will be a bladder layer to maintain the proper pressure dynamic to protect the astronaut and it does this by containing the same oxygen that the astronaut will breathe inside of the bladder layer's confined space.it will be made using a mixture of nylon and polyester

•A layer will be made out sheets of Neoprene and Dacron will serve as thermal insulators.

•The innermost layer will be a liquid cooling layer accompanied by a condenser to prevent loss of moisture from the suit increasing the usability period of the suit .

•Every spacesuits will be equipped with portable life supporting system which will provide a breathable air, food , water and power and assimilation of waste products .

•The spacesuit will be very light weight to provide easy movement. The torso will be loose whereas the lower part will be tight, this will help free movement of the upper body

•Navigation System: LOX and LH2 based jet thrusters at strategic locations on the spacesuits will allow precise maneuvering and faster operations. These will be controlled based on motion sensing.

. An auto rotating tool belt will have the devices required by the user (will be stocked for each trip based on the needs) and as soon as the user selects a device, the belt will rotate and the device would come eject in front of the user.

4.3.4 Human inspection on external rotating volumes

Robots will be used for external repairs. There will a full body teleoperation system for human control of robots. These bots will be controlled by humans in the control center, using virtual reality headsets giving a 360-degree view of the robots environment enabling personnel safety and efficiency. The robots will be well equipped to scan for damages and carry out operations such as pressure less sintering, making an airtight seal etc.

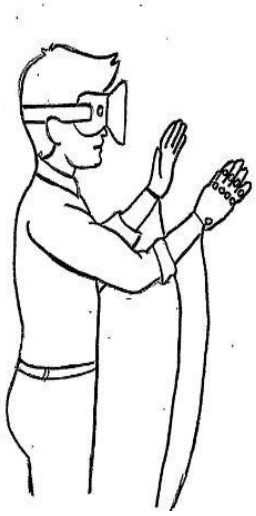


Fig 4.3.5

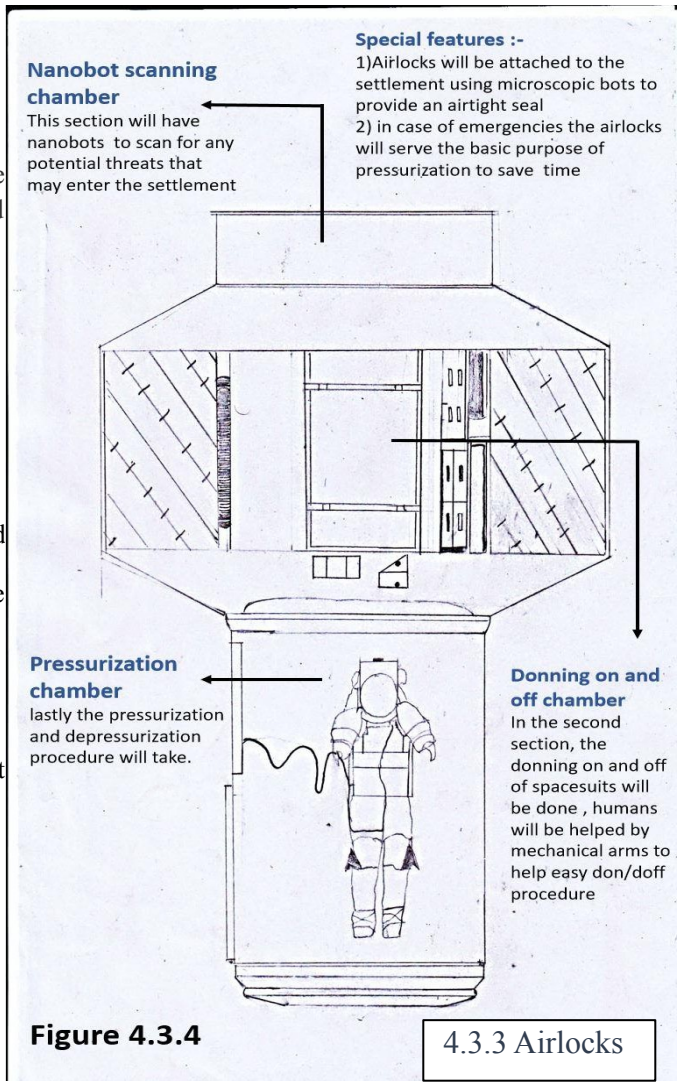


Figure 4.3.4

4.3.3 Airlocks

4.4 Activities and design features in various g levels

Acasal offers g levels varying from 1g to 1/6g, with design features appropriate for each g level and different activities will be conducted in each of the various g levels offered by Acasal.

G levels	Location	Activities	Design features
1g	singularity (residential) cylinder, floor 1 of chiral, cylinder Hubble	Residential areas, parks, schools, colleges, hospitals etc., industrial activities, agriculture	- 1g will help to create an earth like environment for the residents of Acasal. Families with children will be located in this g level to help facilitate bone development of children.
0.88g to 0.52	Chiral floor 2 to chiral floor 4, cylinder Hubble	Residential areas , agriculture , hotels , industrial activities	-carpeted floors to increase friction.spacious homes to prevent collision with walls.padded walls with memory foam and ceiling to reduce impact of collision
0.52g to 0.16 g	Chiral floor 4 to chiral floor 8,, cylinder Hubble	Recreation activities, residence for transient population, agriculture, industrial activities	-Small, private and soundproof booths will be provided which will act as sleep stations and will contain a tethered sleeping bag and padded walls..tethers and handrails available to help manoeuvrability.furniture attached to the floor using magnets.residents will be provided with grappling gloves and boots, which have magnetic systems to manoeuvre through the room

4.5 In transit population

4.5.1 Hotels

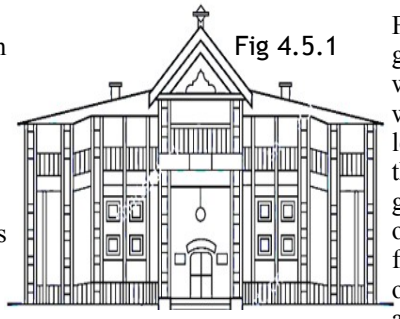


Fig 4.5.1

Up to 600 people can be accommodated in Acasal's hotel - Astral. The structure and interior of this xzhotel is futuristic and homely. Tourists will be able to book various recreational activities through astral. Hotels will have shopping complexes, multiplexes, business centres, gyms, play areas etc.

The golden snitch

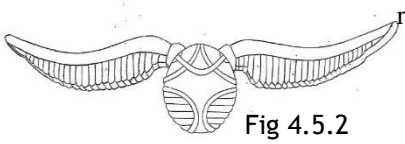


Fig 4.5.2

The golden snitch will be a small drone equipped with proximity and acceleration sensors. The ball will move randomly and participants must pass the racket through the snitch to score, when the ball passes through the racket the sensors identify the ball and it will light up. The game will last 7 minutes and the player with highest score wins. Difficulty levels can be adjusted, microgravity will add to the fun of this game .

Fortnite battle royal

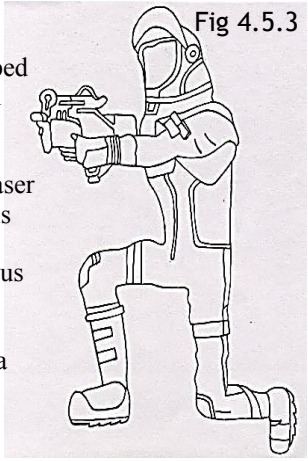


Fig 4.5.3

Fortnite is a survival action game, players will be equipped with anti-gravity suits which will help them to scale the length breadth and height of the stadium and Infrared Phaser guns to tag opponents. Teams of up to 4 players can be formed cooperating on various objectives, collect resources and build holographic fortification for defence. At a time up to 25 teams will be allowed to enter,last squad remaining wins

Rocket football league

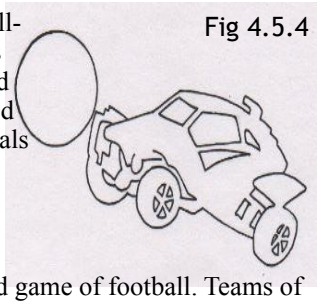
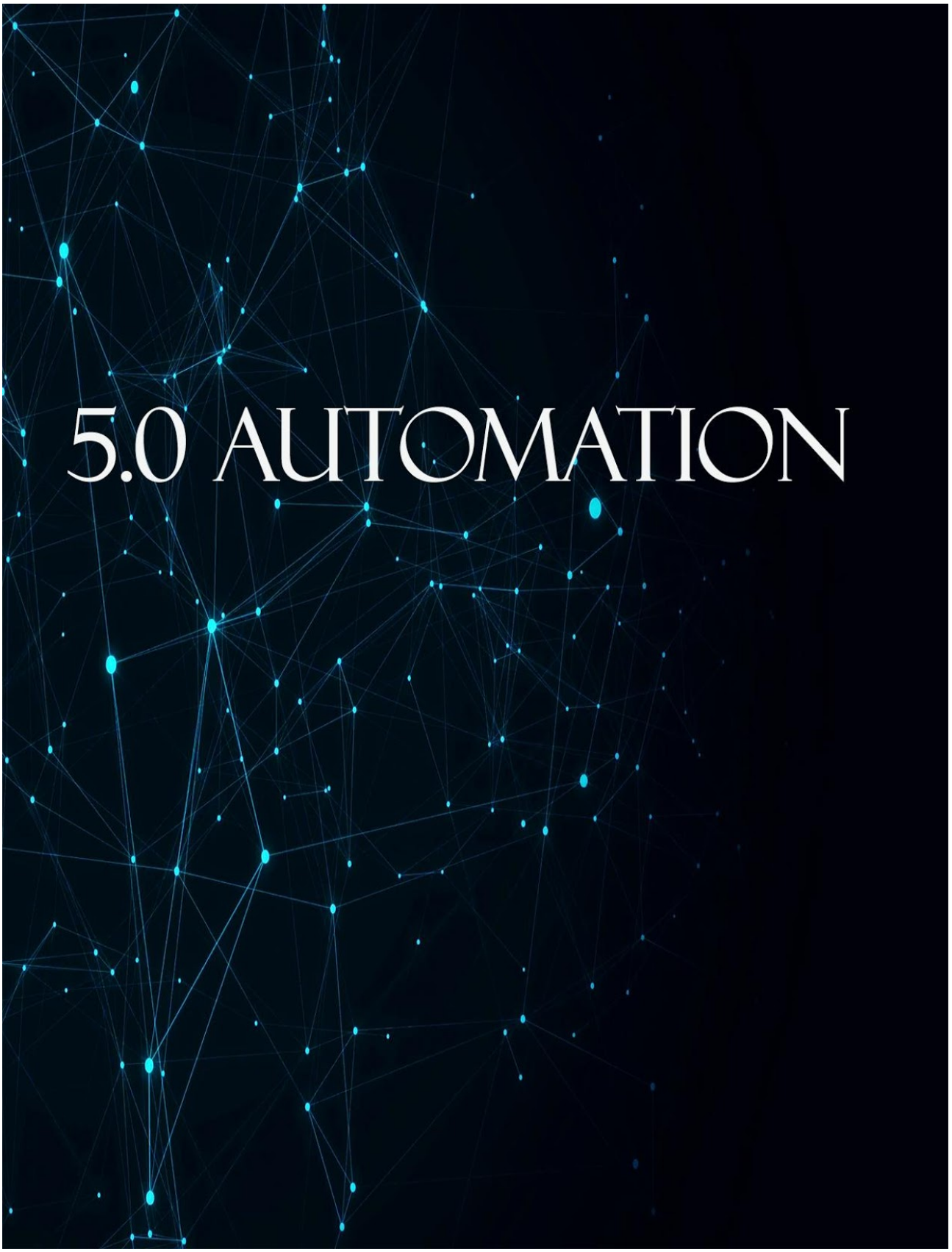


Fig 4.5.4

It is an exhilarating football-Action game which equips players with booster-rigged vehicles that can be crashed into balls for incredible goals or epic saves across the arena. A magnetic system will allow players to drive on walls, in this. unbelievable, re-imagined game of football. Teams of up to 5 people can be formed, each game will last 45 minutes. Annual "Acasal championship" will be held.


5.0 AUTOMATION

5.1.1: Robots Used for Construction:

Name	Features	Dimensions (L x B x H) & Quantity
Porphyrion Exterior Construction bot. (Fig. 5.1.1)	• Has storage area for construction materials. 4 rotatable thrusters allow the bot to move. • A modular design and retractable arms increases efficiency and provides versatility. • To minimise human intervention, the bot utilises Artificial Intelligence in accordance with micro sensors possessing Accelerometers, Gyroscopes, e-Compasses, inertial modules microphones, Proximity sensors which allows the bot to maintain position. • In the last phases of construction, half of these bots become part of the structure while the other half aid in repair maintenance and construction of other bots	10m x 10m x 15m (100)
Pygmy Interior construction & infrastructure instalment bot. (Fig 5.1.2)	• Uses 3D printing for interior construction. • Microscopic bots aid in fusing coating on surfaces. • 10 bots launched from Earth. Replicate once at construction site. • After construction they assume same role as that of *Porphyrion.*	7m x 7m x 10m (150)
Nanobot (Alexandriat`s creation)	• Previously used on *Alexandriat*, *Nanobots* are used to aid *Porphyrion* and Pygmy in construction. • Use Selective laser sintering (SLS) to fuse coatings (refer to section 3.3). • Work in swarms to increase time efficiency. Collected by construction bots using electromagnets after work is done. • They will majorly aid *Porphyrion* and *Pygmy* in the initial construction stages but later on will be used for installing utilities and infrastructure like fabricating microscopic circuits(MEMS) used in many bots. • They will take care of Smooth furnishing of furniture and can make any changes desired.	0.01m x 0.02m x 0.01m (2500)
Inspection bots (MEMS Micro-Electro-Mechanical Systems) (Fig 5.1.4)	• Inspects area around target construction site to aid *porphyrion*. • Inspect exterior hull for damages. Use Computed Tomography to analyse damaged areas and provide control centre with an interactive 3D model of the area. • Strong internal junctions provide resistance from damages. Low mass (250g) lowers production costs.	0.1m x 0.5m x 0.5m (1000)

5.1.2: Transportation and delivery of materials and equipment:

During phase 1, since there is no proper storage, spaceships would store Materials and attachments will be kept in the spaceship which will be docked. The bots will go to the spaceships hull and they themselves will retrieve the materials and different attachments they would need and put them in their storage space. For attachments they will exchange their attachments and store them in the spaceship.

5.1.3: Assembly of the settlement, installing utilities and interior finishing:

The assembly of *Acasal* would be automated which will reduce the time and manual labour and maximizing profit. The *Porphyrion* will build the exterior of the settlement. Simultaneously, *Pygmy* would be responsible for setting up the different floor plans and construct gas, water, and electricity fixtures. Both of these robots would be assisted by *Nanobot* in various tasks.

action would be taken.

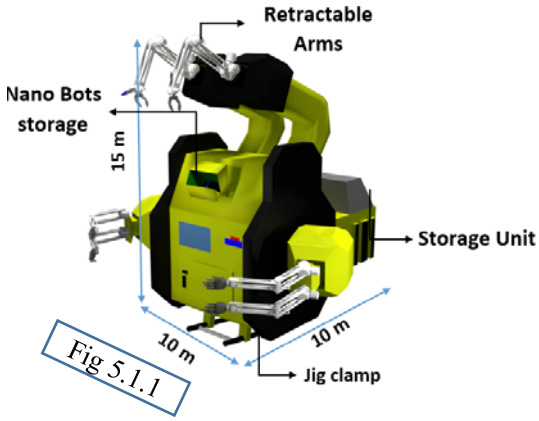


Fig 5.1.1

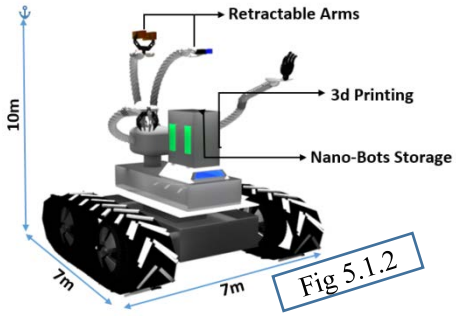


Fig 5.1.2

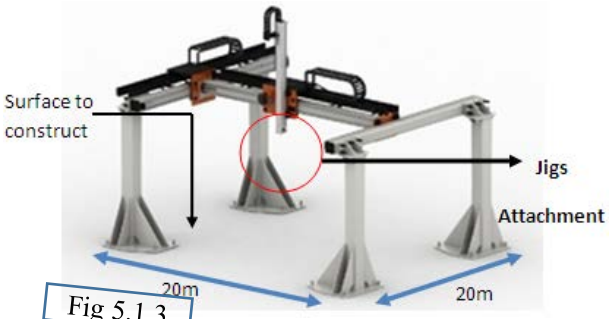


Fig 5.1.3

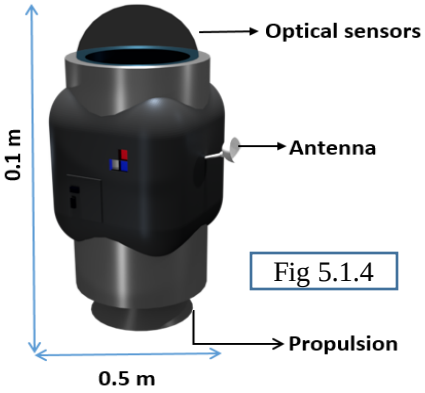


Fig 5.1.4

5.1.4: Jigs usage and lay down in 0g:

Porphyrion lay down jigs with the help of nanobots. The attaching component of the jig gets attached to the robot and allows the robot to move three dimensionally, with the help of a Cartesian system, in a volume of radius 10 metres from the central point of the jig. This will allow the bot to move efficiently in space. The bots will lay down jigs for themselves and then work on that area. (Fig 5.1.3)

5.1.5: Human Intervention:

Phase 1 to 3 includes near to no human intervention and bots work autonomously using their interconnected neural networks to construct the settlement. During the construction of Phase 1 to 3 bots will send crash reports **if any** to earth for further inspections. Post phase 3, control centres are functional hence the construction bot server will get an update which will allow the control centre to control them through Virtual Reality headsets (Refer 5.3 for control centres functions).

5.2.1: Computing Components:

Major Computing Components	Amount	Location	Processing speed	memory	Storage
Main & Backup servers	2	Control Centre	100 GHz , 256-core	8TB of 50GHz DDR12L	1000PB(divided in 500-500 PB for main and backup)
Dept. Servers	4	Industrial Server– Hubble Private Public and Operations Server – Singularity	55 GHz , 128-core	2 TB of 30GHz DDR10L	250 PB
Sub Dept. Servers	12	All Close to Main Dept. Servers	35 GHz , 128-core	1 TB of 25GHz DDR9L	200 PB
Computers	8000	Homes, Control Centre	10GHz, 64-core	521 GB of 30GHz DDR10L	50 PB

5.2.2: Contingency Plans:

Contingency	Initial Response	Secondary Response	Initial Response time
Hull Breach	Valves present in the airlocks connecting the capsules would close, isolating the capsule from the rest of the settlement. The inhabitants of the breached capsule to proceed to contingency pods for safety.	Construction robots would repair/rebuild and subsequently depressurization is carried out.	0.5 sec
Fire	Evacuation of inhabitants, post which fire bot will extinguish the fire.	Assess damage and repair.	15 seconds
Rogue Citizen	*Daimon* alerts security personnel **(Robots will not physically interact with humans)**	Security personnel will respond and arrest or give him a warning.	1 to 5 mins
Air contamination	Area will be completely isolated and inhabitants will be sent to contingency pods.	Air filtration will take place and air composition will be restored.	1 min
Solar flare and radiation	On detection, evacuation of the affected volume is done and the magnitude of the evacuation process is dependent on the intensity of the radiation being received (calculated using sensors)	Assess and repair damage.	3 mins

5.2.3: Data Access Levels:

User	Access Option	Authentication measures	Purpose
Guests (Level 1)	Public computers, access to living quarters	Keycard (temporary it will be removed from the servers within 2-3 days after their visit is completed). Remote access allowed	This will be used to enter specific locations in the settlement for eg their hotel. It will be used in public facilities
Residents (Level 2)	Public/Personal computers, access to homes,	Keycard and fingerprint. Remote Access allowed	It will be used to access their residence and use public facilities
Workers (Level 3)	public/personal computers,access to home and industrial space	Keycard, password, Hand print scan. Remote access allowed.	It will be used to enter the commercial areas and their residential sphere
VIPs (Level 4)	Access to personal computers and space,access to read data uploaded by crew members only with special permission by the captain they can edit the data	Keycard, Hand prints scan, facial recognition and a password. Remote access disallowed.	This will be used to access restricted areas only with permission and access residential and public facilities.
Members of Command Centre (Level 5)	Access to their specific workstations but can override robots and access them (needs access of 2 crew members) manually in emergencies.	Keycard, Hand prints scan, voice recognition Iris & retina scan and 18 characters alphanumeric password with at least 2 special characters. Remote access to data disallowed.	They can access every part of the settlement thus override public facilities. They can access private information if they have authorization by the captain.
Head of the Command Centre (Level 6)	Can override access to anything other than confidential information.	Keycard, Hand print scan, Voice recognition, iris & retina scan, 24 characters alphanumeric password with at least 2 special characters. Remote access of data disallowed.	Can access every part of the settlement Can override any public facility or private information.

5.2.4: Backup Systems and Data Security:

There will be 2 servers, 1 online server and other backup server. When updates come in the backup server will update first and then replace the online server, which will then get updated and act as backup server till another backup is available.

When the servers crash, the backup server will replace the crashed one and he servers will be back online. Honey encryption will be used to encrypt and decrypt all data in the settlement. Honey encryption when decrypted by an incorrect key produces an incorrect data is sent to the intruder.

Robot Name	Properties	Measurement & Quantity (L x B x H)
Hydra (base bot) (Figure 5.2.3)	This bot will be the base design for all the other bots, different attachments will be joint to it, thus allowing it to do different tasks when needs be. This will make maintenance of the bots easier as the bots used for daily purpose will have the same base design, thus allowing • Reusing parts from broken bots • Using one bot for multiple functions. These bots will have 2 designs: sticky wheels for internal (in gravity movement) and thrusters for the external (in 0 g movement). These bots will have 4 joints so that different attachments can be joined for different purposes. The bot will have a 360° rotatable base. The bot will have a variety of sensors like dynamic force sensor, laser ranging sensor, gyroscope, etc.	0.6m x 0.5m x 0.4m (5000)
Hygieia attachment (Fig 5.2.2)	It is an attachment on the hydra which will provide it with a vacuum cleaners on both the arms to clean around the settlement. It can be also controlled by a phone app (only for personally owned *Hygieia* bots) which will be needing human intervention.	0.8m x 0.5m x 0.5m (300)
Poseidon attachment	It is also an attachment on *Hydra* which will provide it with a fire hose. Receives real time information of fire events through *Heimdall*. Spray dry powder in small quantities compensating for low storage. Multiple *Poseidon* units combine to form a bigger unit in case of wild fire.	0.6m x0.5m x 0.5m (60)
Dobby attachment	It is an attachment on the Hydra. Helps in residential chores. It will also have a scanner which will keep a check on the health of humans around it and will report the medical bot if needs be.	0.6m x 0.5m x 0.5m (4000 , one for each house)
Codex (Fig 5.2.1)	Refer (5.3.1 4th part)	0.15m x 0.007m (7000)
Epiones (Medical bot)	Has varied tests which help in creating a medical profile for citizens for future reference. Works with the Transportation Medical Bot to give the patient everything he/she needs, from glucose to blood from blood banks.	0.5m x 0.4m x 0.4m (80)

Trade Study of Usage of Material for Fire Extinguish

Dry Powder	CO2
It can be used safely up to 1000 volts	It can be safely used on both high and low voltage
It can extinguish- Class A, Class B, Class C, Class D and Electrical components.	It can extinguish- Class B and Electrical components.

Thus, we will be using both of them but we will have lesser of CO_2 because it can extinguish lesser stages of fire than dry powder and CO_2 will be placed near electrical components.

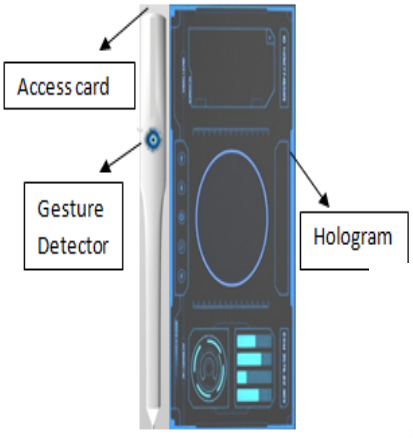
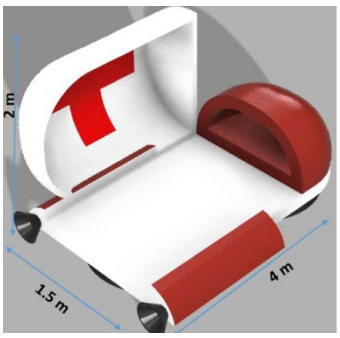


Fig 5.2.1



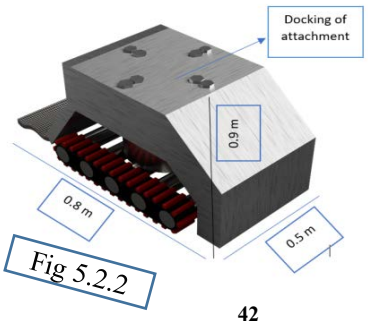


Fig 5.2.2

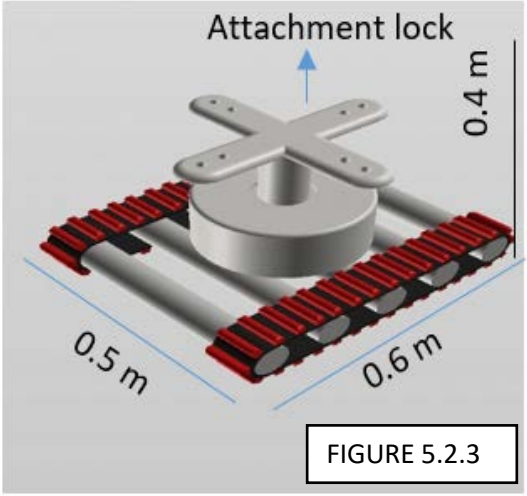


FIGURE 5.2.3

5.2.5: Automation for Security:

Robot Name	Properties	Measurement & Quantity
Daimon	This bot will be an attachment to the base bot (Refer 5.2.5). This attachment will have a 360° rotating camera these cameras can record live CGI for later 3D inspection. Analyses human behavioural patterns to impart alerts before a crime is committed. It will have its own GPS and can give its location to the control centre.	0.6m x 0.5m x 0.5m (200)
Heimdall	These camera will record only in human presence. It will have the capability to record human movements with the help of CGI sensors.	0.3m x 0.1m x 0.1m (350)
Robots will not physically interact with humans in a threatening manner		

5.3.1: Home Automation:

1. *Wireless CPU Sharing*: There will be a private server for every house. This server will be wirelessly connected to peripherals which will act as an access point and will be sharing I/O systems hence

2. *Dobby*: This butler bot has the major purpose of cutting down on manual labour. (Refer 5.2.5)

3. *Smart table*: It will be connected with the server and would have its display on its glass which can also be converted to a holograph using a holographic sensor and 2 cameras for projection and 1 microphone which will be placed centrally for gesture and voice recognition. It will be used in control centres and homes.

4. *Codex*: This device would be a hybrid device and will be used as an access card and a personal device. Its interactions will be on the basis of hologram which will be controlled by gestures. It will be connected with the CPU sharing server thus making it light as it does not require any chip or internal connectivity other than the wireless connectivity. It will also lead to easy data sharing.

5. *Entertainment Window*: There will be transparent LED windows in homes. These windows would be connected with microphones and speakers which would be spread all around the house this will also enable it with speech recognition. The windows will help us to save space in the homes.

5.3.2: Privacy of Personal Device:

All personal data would be stored in personal home servers which will be connected to *Codex*.

1. The personal data stored on *Codex* would only be accessible to the user as *Codex* would use non-invasive sensors to record unique bio markers of the user, it would use these markers as a security checkpoint. It only uses data of the user to provide a personalised experience.

2. In case of special circumstances, Control Centre will have access to secure data. If there is a rogue citizen, all personal data shall be made available to Security Personnel. The system firewall can only be over ridden to access personal information if and only if the head of the command centre and at least half of its crew members agree on disclosing it, thus making a monopoly and maintaining the integrity of security. (Refer section 5.2.3)

3. All data would be secured through honey encryption making them unsusceptible to hackers (Refer section 5.2.4)

5.3.3: Control Centre

According to Nasa's 2015 study on control centre, we have followed the key ideas on IOT. In our control centre we will be having 15 tablets and Virtual reality headsets to control the exterior construction bots, these tablets would be integrated with the personal device. To enter the control centre you will have to 1- insert your personal codex 2- enter the alphanumeric password 3- give your biometric scans.

Table 5.3.3 Uses of Touch pads in Control Centre

System	Sphere of control	Reason
Touch pads 1-2	Malfunctions	To assign robots to places which are suffering from a defect or any kind of malfunction
Touchpads 3-8	Communication with robots	To enable simultaneous communication with bots. This will also be used with VR headsets to control the exterior construction bots.
Touchpads 9-12	Storage management	To manage the storage of goods and commodities in warehouses.
Touchpads12-15	Security overview	To control the security cameras and security bots of the settlement.

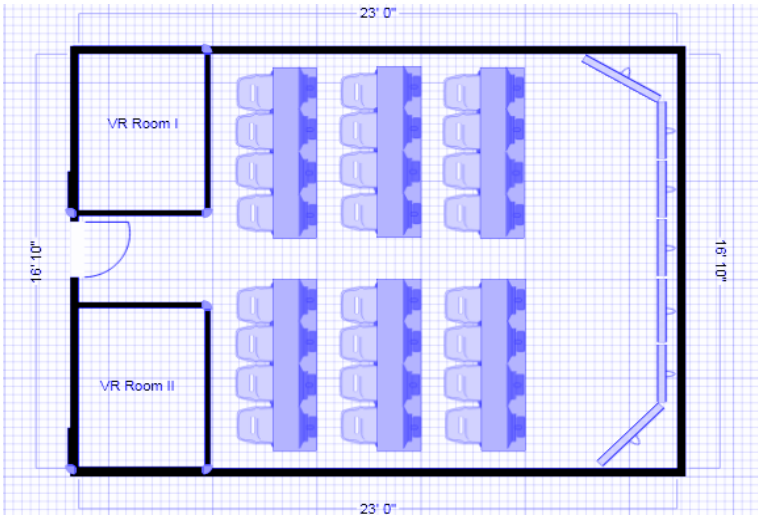


Fig 5.3.3 Uses of Touch pads in Control Centre

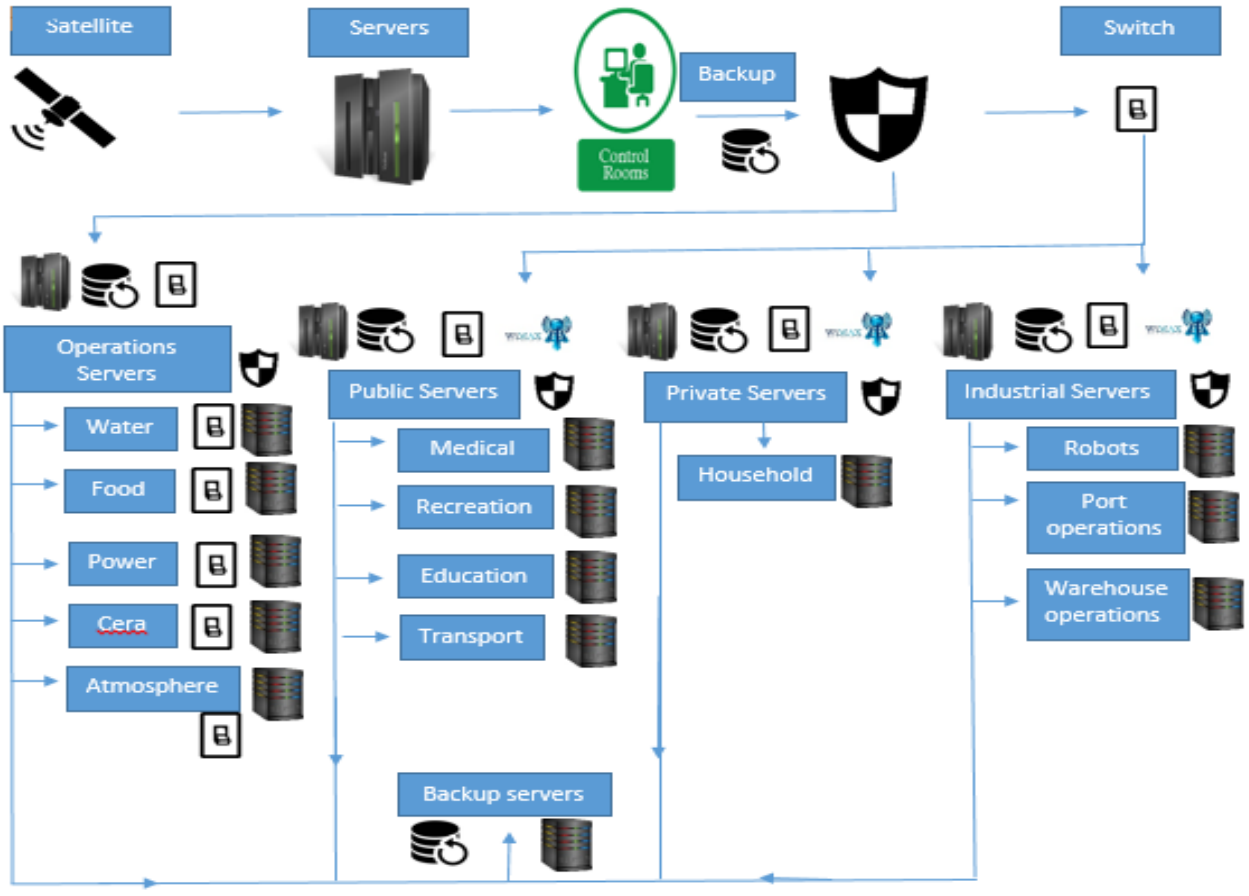
5.3.4: Internal and External Communications:

(Refer to 3.2.6)

5.3.5: Control of Systems in Private Space:

The Controlled Environment, provided to the residents of *Acasal* has the ability to control systems in private spaces such as temperature control, humidity and entertainment systems like televisions and all-round music systems along with all operations of *Dobby*. And all these facilities can be accessed by voice control from anywhere.

5.3.6: Community Interconnectivity and Information Exchange:



5.4: Port Automation

5.4.1: Robot Usage:

Name	Functions	Quantity and Dimensions (L x B x H)
Loader/ unloader bot	• Acts as transit loader and unloader of cargo/CASSCs between ships/space elevator and 0G transporter bot that transports cargo. • Uses mechanical arms and forklift to handle cargo, and loads it on *Oler* that further transports it.	4.5m x 2.75m x 0.5m (100)
Oler (Fig 5.4.1) (0G transporter)	• Transports CASSCs between warehouses, space elevator & ports. • Have light magnetism and thrusters to carry CASSCs efficiently.	9.5m x 4.75m x 0.5m (100)

5.4.2: Autonomous Port Operations:

1. <u>*Fuelling*</u>: CASSCs are repurposed to be fuel tanks which will be carried by *Oler*. Liquid oxygen and RP-1 will be stored in these repurposed CASSCs. These repurposed CASSCs will have a nozzle acting as a fuel outlet.
2. <u>*Loading / Unloading*</u>: The base bot will have a pistol grip tool attachment. This tool will enable the bot to repair the damage with precise amount of torque.

5.5: Automation in Warehouse and CASSCs Handling:

Name	Functions	Dimensions & Quantity
Forklift robot (Fig 5.5.2)	This robot will be used in the warehouses to load and unload cargo, then it will put the cargo on the commercial transportation bot.	4.5m x 2.75m x 0.5m (75)
Bumble bee (Warehouse)	This bot will be used to transport/move the CASSCs around the warehouse and to the area where g area ends and 0g area starts.	9.5m x 4.75m x 0.5m (75)
Scanning bot (Fig 5.5.1)	The scanning bot will identify defects and conduct high quality checks on CASSCs through ultrasonic waves. It will also scan their identification number.	0.5m x 0.1m x 0.1m (50)

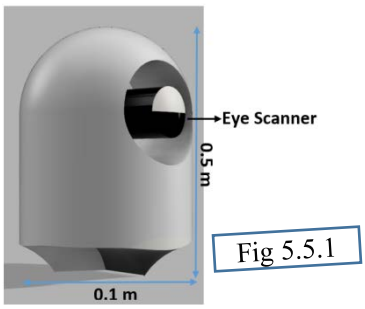


Fig 5.5.1

At Acasal, CASSCs will be handled by an effective autonomous system of bots. Each CASSC will be given a unique identification number which will be used for identifying and locating the CASSC. When the system receives a request for transporting CASSCs, the scanning bot will locate the CASSC and send the location of CASSC to forklift robot. Forklift robot will retrieve and put it on *Bumble Bee* for further transportation. The CASSCs will be arranged in a rack made of a very low powered magnet with beams on the side to provide stability. This arrangement ensures retrieval of CASSCs is possible at any point of time. Storage in 1/6 g area allows easy handling.

Fig 5.5.2

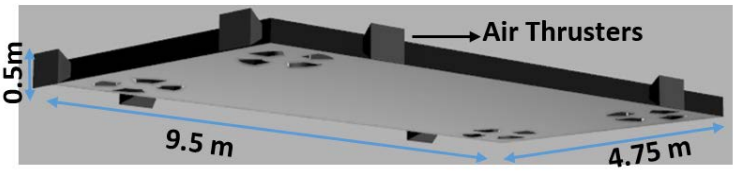


Fig 5.4.1

Additional Features

In Acasal we will try to provide the best liveability experience to our residents. Automation in Acasal will work on every minute and small detail possible -

- Gyms in the settlement would be equipped with headsets and projections that can project any place the user wishes allowing the user to run a marathon on Jupiter or go for a soothing walk in the Sundarbans. These headsets can also be used collectively to help us conduct ACASAL marathons. These VR headsets can be connected to codex by which the residents can get notified about the happenings around them without removing the Headsets.

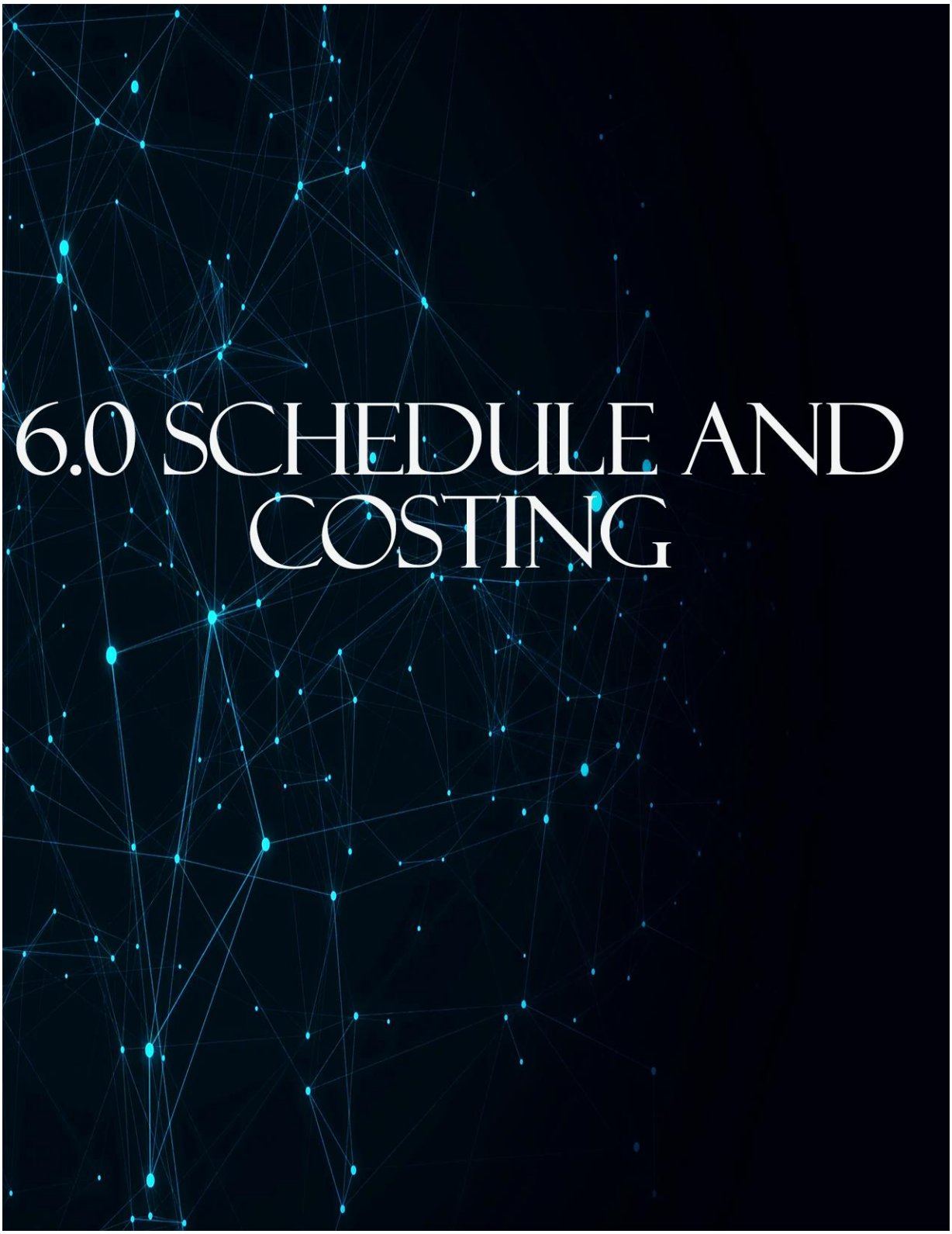
- The lighting and temperature is set in all areas to enhance productivity. In accordance with research, we have used blue light in work places to enhance productivity. Also, keeping day period slightly longer than night period in day night cycles helps increase number of productive working hours.

- Considering how huge *Singularity* is in its down surface area, travellators are added along roads to make on foot transportation faster.

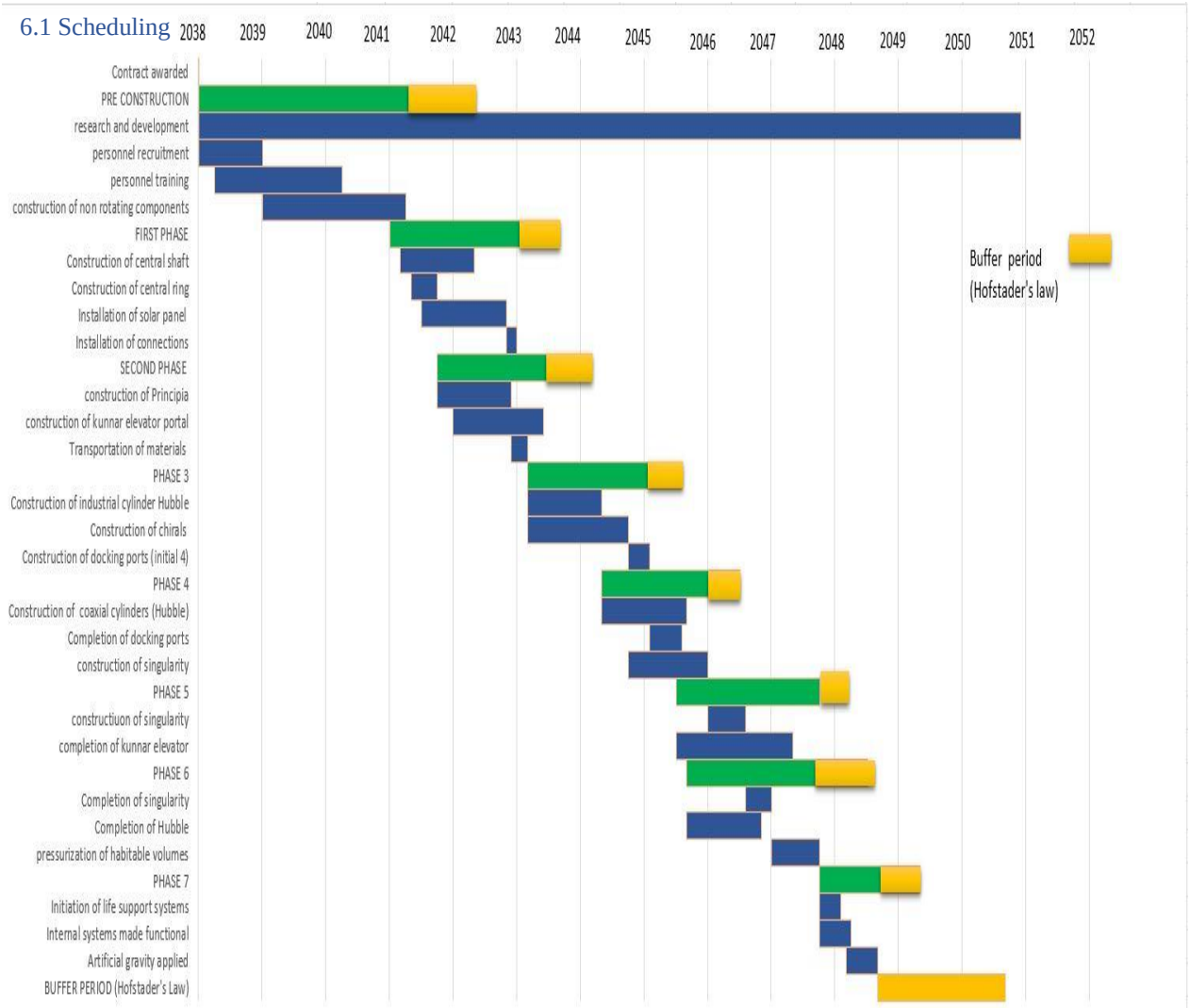
- There will be a replicating Model which will consist of four bots who will perform different functions used for this process which will be an unmanned and autonomous process and will take the help of nanobots for binding the small parts to the main body. Replicating bots will possess a welding arm and will have a joint for future upgrades.

- The bots which cannot be repaired and are useless to the settlement are utilized in a very special way. The materials of these robots would be used to repair the other robots or the structure.

- There are separate switches for operation in server mapping because operation is the key point on which the settlement depends due to different switches we can reboot the different aspects of the operations in settlement rather than rebooting the operations of the whole settlement which will affect the working of the settlement.


6.0 SCHEDULE AND
COSTING

6.1 Scheduling



EMPLOYMENT DIRECTORY	ANNUAL SALARY	NO. OF EMPLOYEES	COST
Engineer	140,000	1843	258,020,000
Data Scientist	160,000	43	6,880,000
Medical Professional	180,000	579	104,220,000
Corporate	150,000	943	141,450,000
Others	158,000	2592	409,536,000

MAINTENANCE	COST
Interior buildings	985.000.000
Robots	2,650,000,00
Communication server	700.000.000
Operations and systems	3.400.000.000
TOTAL	7.735.000.000

PRE CONTRUCTION	COST
Research and development	1,500,000,000
Personnel recruitment	750,000,000
Personnel training	2,000,000,000
TOTAL	14,250,000,00

PHASE 1	COST
Construction of central shaft	17.350.000.000
Construction of central ring	5.000.000.000
Installation of solar panel	1.950.000.000
Installation of connections	250.000.000
Total	24.550.000.000

PHASE 2	
Completion of principa	12.900.000.000
Construction of kunnar	250.000.000
Transportation of materials	4.700.000.000
TOTAL	17.860.000.000

PHASE 3	
Construction of industrial	15.000.000.000
Construction of chirals	18.800.000.000
construction of docking ports	12.650.000.000
TOTAL	46.450.000.000

PHASE 4	COST
Construction of Hubble	5,000,000,000
Construction of singularity	12,460,000,000
Completion docking ports	3,750,000,000
TOTAL	21,210,000,000

PHASE 5	COST
Construction of singularity	7,850,000,000
Construction of kunnar elevator	2,420,000,000
TOTAL	10,270,000,000

PHASE 6	COST
Pressurization of residential volumes	700,000,000
Completion of Hubble	1,250,000,000
Completion of singularity	350,000,000
TOTAL	2,750,000,000

PHASE 7	COST
Initiation of life support	430,000,000
Internal systems made	660,000,000
Artificial gravity applied	250,000,000
TOTAL	1,340,000,000

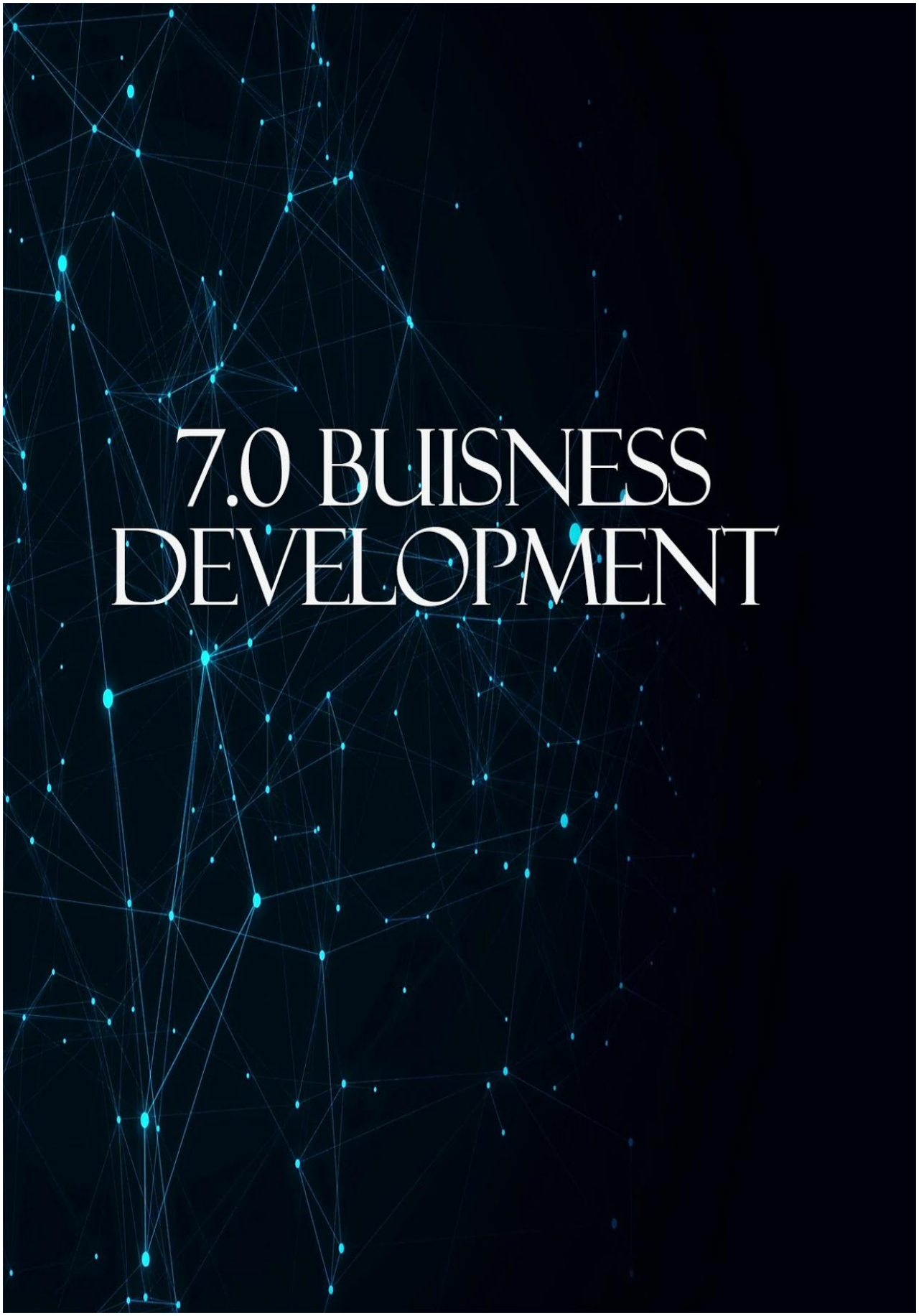
HUMAN FACTORS	Price per unit	Quantity	Total
traditional small houses	450,000	1600	720,000,000
traditional large houses	500,000	150	75,000,000
modern small houses	175,000	1400	245,000,000
modern large houses	250,000	150	37,500,000
contemporary small houses	170,000	1400	238,000,000
contemporary large houses	210,000	150	31,500,000
Football rocket league arena	600,000,000	1	600,000,000
Fortnite arena	300,000,000	1	300,000,000
amenities	100,000,000	1	600,000,000
TOTAL			2,847,000,000

AUTOMATION	Price per unit	Quantity	Total
Porphyrion	450,000	100	45,000,000
pygmy	350,000	150	52,500,000
Bumble bee bot	150,000	75	11,250,000
Oler bot	100,000	100	10,000,000
Hygeia attachment	20,000	300	6,000,000
Hydra bot	250,000	5000	1,250,000,000
Dobby attachment	20,000	4000	80,000,000
Poseidon attachment	35,000	60	2,100,000
Hephaestus attachment	40,000	100	4,000,000
Heimdall	75,000	350	26,250,000
Codex device	14,500	7000	87,000,000
nanobots	120,000	2500	300,000,000
Inspection bot	130,000	1000	130,000,000
Diamon attachment	45,000	200	9,000,000
Loader unloader bot	125,000	100	12,500,000
Forklift bot	125,000	75	9,375,000
Scanning bot	60,000	65	3,900,000
			2,053,500,000

MATERIAL	Price per unit volume	volume	COST
Bucky structure	4.7	790976.45	3,717,000
Titanium oxide infused Bucky structure	113.5	790421.97	89,800,000
Water	5	419823.70	2,099,000
G10/fr4 glass epoxy + CNT	120	408687.04	49,042,000
Magnesium infused silicon carbide	164	787111.27	129,086,000
Lunar regolith	6.34	402147.95	2,550,000
Bucky structure shutter	6	12703.03	76,000
Transparent aluminum	273	12203.63	3,330,000
TOTAL			230,000 ,000

The Total cost-

$143,800,500,000


7.0 BUISNESS
DEVELOPMENT

7.1 Port for visiting orbital ships

The ports will be functional in the starting stages of phase 3, establishing IOC. The precise port designs allow space optimization. *Principia* can dock spaceships of all sizes, and each one of *Principia*'s ports has an airlock for safe transportation from the depressurized space outside to pressurized and habitable volume inside. This process is followed by customs at the port *further explained in 2.5*. As at any point of time, only 4 ports are needed to be operational, Acasal has an added advantage of having 8 ports which are of 4 types. The backup ports, *referred to in 2.5.3.4*, are opened in traffic overflow, emergencies or for maintenance. Different ports have different capabilities and uses which results in division of labour as no port gets overused, and this variation in types are further *explained in 2.5.3*. Lastly, every port will have refueling points with adequate fuel and provisioning, limited repair services, and automated mechanisms to assist with docking which will ensure a safe transportation and maintenance system to or through Acasal.

7.2 Storage of in-transit CASSSCs

The warehouses are located near the edge of the cylinders facing *Principia* and store food and various items (*explained in section 3.2.2*). The warehouse closest to the entrance hosts CASSSCs (both for long term storage and in-transit CASSSCs) which can reach the port or the space elevator average within 1 min 17 seconds which are directly connected to the *Hubble*. The warehouse for CASSSCs will be built by the ending of phase 4. So, between Phase 3(Where IOC is established) and the ending of phase 4, , they will be stored at a port facing *Hubble* and could carry up to 200 CASSSCs. The port will be freed of this duty when Phase 5 is started and then the warehouses inside *Hubble* will be used. In the case of the operating capacity is exceeded, then the CASSSCs will be transported through multiple paths, thus offering no hindrance to the transportation system.

7.3Base for lunar shuttles

The passengers and cargo travelling in the lunar shuttles will pay customs, which will act as a source of income. The port facing the moon near the end of *Singularity* will be the point of boarding, fueling, repairing these shuttles and in case the port is not sufficient another multipurpose port will be provided for the same. At phase 6 (referred to in 2.3), the base will be complete and will have the capability to launch as well as catch incoming type 2 configuration shuttles which have minimal guidance propulsion using a mechanism called *Arcus* which will be a large low-pressurized curved surface connected to an automated arm will cooperate with *Acasal* and upon predicting its trajectory, will capture the shuttle resulting in safe transport. In case of a system failure, the shuttle has enough tensile strength to take a rough landing on Luna multiple times. Then, it would undergo MRO (maintenance, repair and overhaul) to reach its optimum condition. The lunar shuttles will undergo MRO after every 3 flights to Luna. Along with this, there will be a fueling depot which will be restocked when the fuel reaches less than 17%. After *Acasal* is built and the settlement is in use, the base will be expanded from all directions and more *Arcus* will be built to garner for higher traffic. Lunar vehicles will be available for exploring Luna, while the type 1 configuration shuttle will periodically travel to *Alexandriat* and transport its resources mined.

7.4 Research Scope and Agriculture

For research purposes, *Acasal* will have agriculture at different g levels to find the optimum conditions to facilitate growth. After the completion of construction for settlement, spaces will be available inside agricultural areas to be loaned out to MNCs for their agricultural research. This will also add towards the income. Also, excess food grown in these areas will be divided and a part will be stored in silos (including contingency plans) and the remaining will be exported to earth where *Acasal* will sell space food at different g levels thus also assisting in earning money.

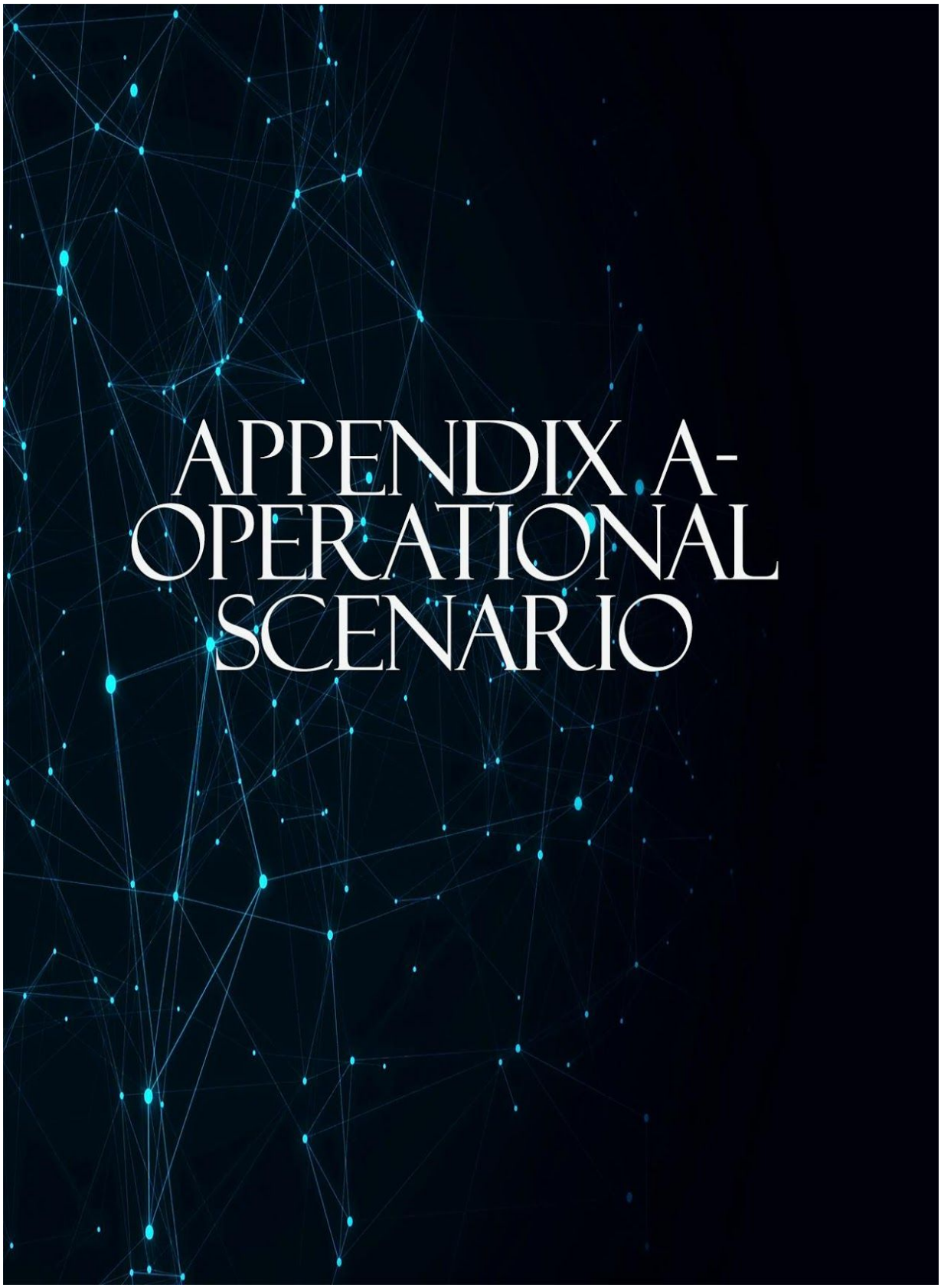
Component	Reference section
Decontamination process	2.5.5
immigration and customs	5.2.4
Variations in ports	2.5.3
Backup and multi-purpose ports	2.5.3.3; 2.5.3.4
Food storage and warehousing	3.2.2
Phases of construction	2.3
Mechanism for ports and bases	5.2
Mined resources	3.1.2
Agriculture at different g levels	3.2.2 ;2.1; 4.1

Table 7.1.1

Source of Income	Revenue generated (per year)
Agricultural space loans	$4952000000
Repair and fueling in ports	$1500000000
Passenger and cargo for lunar shuttles	$2322320000
Mined resources sold at earth	$179643320
Exploration of Luna	$298762800
Travel to Alexandriat through space shuttle	$1181984780
TOTAL	$10,434,710,900

Table 7.5.1

Based on the cost recovery expectance presented in table 7.5.1, Acasal will recover all initial investments in 14 years.


APPENDIX A-
OPERATIONAL
SCENARIO

2038. Nearly 70 years of intense research, mind-bending insights, and pure perseverance and perspiration stood before the shuttle- a magnificent symbol of the times to come. The colossus was sailing through what went from ether to a vacuum, a history in faith and fantasy. The shuttle was alive. It buzzed with anticipation, and in the middle of a sea of white specks, the passengers' eyes glistened- with excitement on one level, and hope on another. One group- a family of four- was particularly excited. While Acasal might have been a landmark in space design and history, it was something different for them- an object of wonder, of genuine awe.

Arya: We're here! The settlement's enormous!
Nat: It's amazing! It looks like the port's clearing up.
Stephen: I'm really psyched for this. I read up on the settlement before the launch, and the science and machinery that keeps it going is genuinely interesting! For example, since this ship has passengers in it, we're actually passing through a larger airlock than the others the settlement has to offer.

A platform began to emerge from the dock, and attaching the shuttle to itself, began to retreat inside. The passengers and their cargo were separated, both heading off to separate decontamination areas.

Lara: What happens now?
Stephen: Decontamination. We've come from Earth, a place where the presence of dust in air doesn't really matter. Moreover, we may be carrying certain harmful organisms with us.
Arya: So they're going to clean us up, right?
Stephen: (Laughing) Yes, yes they are.

The family went through the process of decontamination, with an emphasis on dust mitigation.

Lara: Where is our luggage going?
Stephen: Remember when we first boarded, all our stuff was stored in a number of giant boxes? I forget the name.
Lara: CASSSCs.
Stephen: Yeah, those. The settlement has separate robots to unload them and transport them. Handling them separately is much more efficient than having us pick them up, like we do in airports, to an extent.

Two women approached the family- Leia and Rey.

Leia: Welcome aboard Acasal! I'm Leia and she is Rey. I hope you had a pleasant flight.
Rey: Your luggage will be handled by REX, our loading and unloading bot, and LEX, our transporter. In order to maximize efficiency in transportation, particularly between warehouses, the space elevator, and the ports, LEX is equipped with light magnetic capabilities and thrusters for carrying CASSSCs. All of your belongings occupy one third of the CASSSC they were originally stored in.
Leia: Each CASSSC will be given a unique identification number, which will be used for identifying and locating it. Later on, when the system receives a request for transporting CASSSCs, the scanning bot will locate it and send its location to forklift robot. The forklift robot will retrieve it, and put it on Bumble Bee for further transportation. The CASSSCs will be arranged in a rack made of a very low powered magnet with beams on the side to provide stability. This arrangement ensures retrieval of CASSSCs is possible at any point of time.

Nat: That went way over my head, but… Your names! (beaming)
Leia: (Laughing) We're aware of that. By the way, do you want your very own lightsaber?
Lara: I don't think he'll ever want to leave after *that*.
Nat: YES- I mean, if you don't mind, of course.

Rey: Here you go. This is your personal device- the codex. Each of you gets one. You can use it for communication, accessing general information about the settlement, etc.

Wondering what he could do with his new saber, Nat pressed a button on it.

Codex: Hello *Nat*, welcome to a new world.
Nat: Umm, do you have any games for me?
Codex: Patience you must have, my young Padawan.
Nat: Oh my god.

Rey: Let's move on, shall we?
Stephen: Yes, of course.

26th January 2038
Acasal, Day One

Lara: Finally, we're here! The infamous Astral Hotel. Stephen, you have been talking so much about it.
Stephen: And now you see why. The Astral hotel chain is the finest of our most luxurious imaginations. It's located on four floors, each in a different Chiral. We are currently on the second floor from top. Now, as per the guide, we will be ushered to our rooms by a robot named Dobby.
"Here I am!"
Lara was startled a moment.
There was Dobby.
Arya: Mum, I think I forgot my socks back home.
Dobby: Don't you worry! I'll be taking all of you to *Singularity* this Thursday. You can buy as many pairs as you please from the mall. And, you know, you can keep all of them.
Arya was speechless.
Nat: This place, it's so different and yet unlike what I imagined it to be.
Arya: I agree, kid brother. This place, it reminds me of a book.
Dobby: Is it Origin, by any chance?
Arya: Yes, yes! Dan Brown in his book mentioned this very famous Spanish architect, Antoni Gaudi who took inspiration from nature for all his buildings.
Nat: Well, that explains the fish scales on the roof of the hotel.
Dobby: Yes indeed! The entire architecture of this place is inspired from the 19th century architect.
Stephen: It's rather ironic to find him inspiring a place where nearly everything is manmade.
Dobby: Oh yes it is! Arya, I must say I'm glad the youth today acknowledges the works of famous authors before your time.
Arya could have spent the next hour talking about how she got complimented by a *robot*, but as they entered the hotel, there was so much more to surprise them.
Dobby: Alright- so, ladies and gentlemen, you are inside the best hotel you will find in the universe, and I do not just mean it figuratively. Make yourself at home and try out all our services. Do remember to book in for all the recreational activities at the Reception!

Nat: Mother, I am starving. It's been light years since I had a ham sandwich.
Lara: Light years is not a measure of time, Nat. We are heading for the cafe, I heard some people say that they have really nice pancakes!

(at the cafe)
Stephen: So, what do you all want to eat?

Arya: I can't believe they serve all the things we would find in any cafe back home. Have you any idea how they get all the ingredients, Dad?
Stephen: I do, but first let's place an order!

(on the table)
Stephen: Yes so Arya, you asked me how they get the ingredients, right? Everything's grown onboard the settlement; from the massive steak you made us pay for to the vegetables we had to force down your throat. They grow crops in special modular boxes that connect to each other- think legos with little plants inside them. Inside the boxes, there are pipes carrying nutrients to those plants, and instead of soil, they use gases and water for transferring them. This way, it's much easier to handle, and it saves a ton of water too. As for meat, eggs, and dairy products, they're grown artificially, via different forms tissue culture. It's hard to tell, though- the food tastes the same!
Arya: So that means, nearly everything we ate was fake?
Stephen: No, no, no! The meat is cultured from an original supply of real animal DNA, so it's nothing like the alternatives we had back on Earth, like soya- it's the real deal. Plus, even with the eggs and dairy, the nutrient contents are almost identical to the originals.
Nat: Fake or real, I could unload on Acasal itself just for this ham sandwich. Mother why don't you make such delicious ones at homes?
Lara: Of course, I shall practise cooking for your fussy tastebuds, Sir.
Arya: But, is that possible anymore? I mean, do Acasal citizens cook food like we do on Earth?
Stephen: It's quite interesting, really. Instead of using traditional stoves or cooktops, the houses here have special induction cooktops and forced air convection ovens. This way, the amount of smoke and harmful substances generated is minimal. Moreover, forced air convection heats the food more evenly, because of which the processes of cooking and drying are much more efficient.
Lara: This family never really gets tired of food talk, right? Hon, what do we have planned for today?
Stephen: It's a game called Fortnite Battle Royal. It's on this Chiral floor itself, surrounding the hotel complex. I've booked us in for the evening, so once you are all ready, we're good to go.
Nat: I am good to go. Let's leave, Dad; if we wait for Mum and Arya to get ready, we'll have to start unloading our stuff here itself. Now that's not at all a bad idea, but the game - let's go!
Arya: Are they even going to let you play, kid brother?
Nat: Of course I'm allowed to play!
Stephen: Well I am not too sure about that, we'll find out soon enough.

(at the Fortnite Battle Royal Stadium)
Stephen: Here we are! I'll go check us in and and make the payments and (looking down at Nat) see if you are allowed to play (wink).
Nat: Oh you're evil, Dad! Don't you see how stressed I am? I came all the way from Earth.
Stephen: Well, well, I just confirmed with the supervising personnel. They said that every activity on Acasal is customisable to meet safety requirements of all age groups. So you can play, Nat, but you will have to play with children your age.
Lara: How much did they charge? It must have been a fortune.
Stephen: Actually, they charged me nothing. All activities on Acasal are free of cost for the first one month.
Lara: Well that's great. So, who is briefing us?
"I am."
The Smiths turned around. So did about a hundred more people.
"Hello everyone, my name is Jane and I work as a Systems Engineer for the Recreational Wing of Acasal. I will be supervising your match today. Now as you might have read on your CodeX devices or even played similar games on your Xbox or PS4 back home, Fortnite Battle Royal is a survival action game. You will be divided into teams of four and you will be required to fortify your surroundings and collect resources. Each one of your will be issued an

artificial gun and an anti-gravity suit. You can play the game with all due focus since safety is being taken care of human supervisors and rescue bots."
Stephen: Okay then, Nat, best of luck! Lara, Arya, come along, let's get our suits.

(back at the hotel)
Nat: That was the best match of my life! Dad, can we go there again tomorrow, please?
Stephen: We could, but we have many more exciting things to do. Goodnight, everyone!

27th January 2038
Acasal, Day Two

Arya: Good morning everyone! So what does Acasal have in store for us today?
Stephen: We have to ascend a Chiral floor, to the topmost level, where we'll be playing Golden Snitch and then we have a visit to the Observation Deck.

(Golden Snitch Arena)
Stephen: Golden Snitch is a comparatively easier game, I suppose. You just have to pass the Snitch through your racquet.
Arya: You look incredibly confident, Dad.
Nat: Of course he is! You'll be able to see it in the match.
Arya: Will I? Okay Mum, we have to beat that confidence.

(leaving the Arena after the match)
Arya: Hey Nat, remind me again, what was your score?
Nat: Ugh, five.
Lara: And what was ours, Honey?
Stephen: Stop this, both of you. We dare you to a match of Rocket Football tomorrow.
Nat: Yes, we do! Dad, where's the Observation Deck?
Stephen: It's down in the Central Ring. We'll take an Elevator to the Central Shaft and from there we land into the Ring. It's only about 300 meters away.
Arya: What exactly will we see there?
Stephen: Have some patience, child!

(Observation deck)
Stephen: Here you are. Have you got your answers, Arya?
Arya: Dad, I don't know what to say. This is the most beautiful view I've ever seen. It's quite literally, out of the world.
Stephen: *When you look at the stars and the galaxy, you are not just from any particular piece of land, but from the entire solar system.* The first Indian-origin woman in space, Kalpana Chawla said that.
Nat: The Earth and Luna from a single place, I can't believe it!
Lara: And all of it, in zero gravity? It's like floating in space. I feel like I can hang glide from one side to the other of the entire settlement.

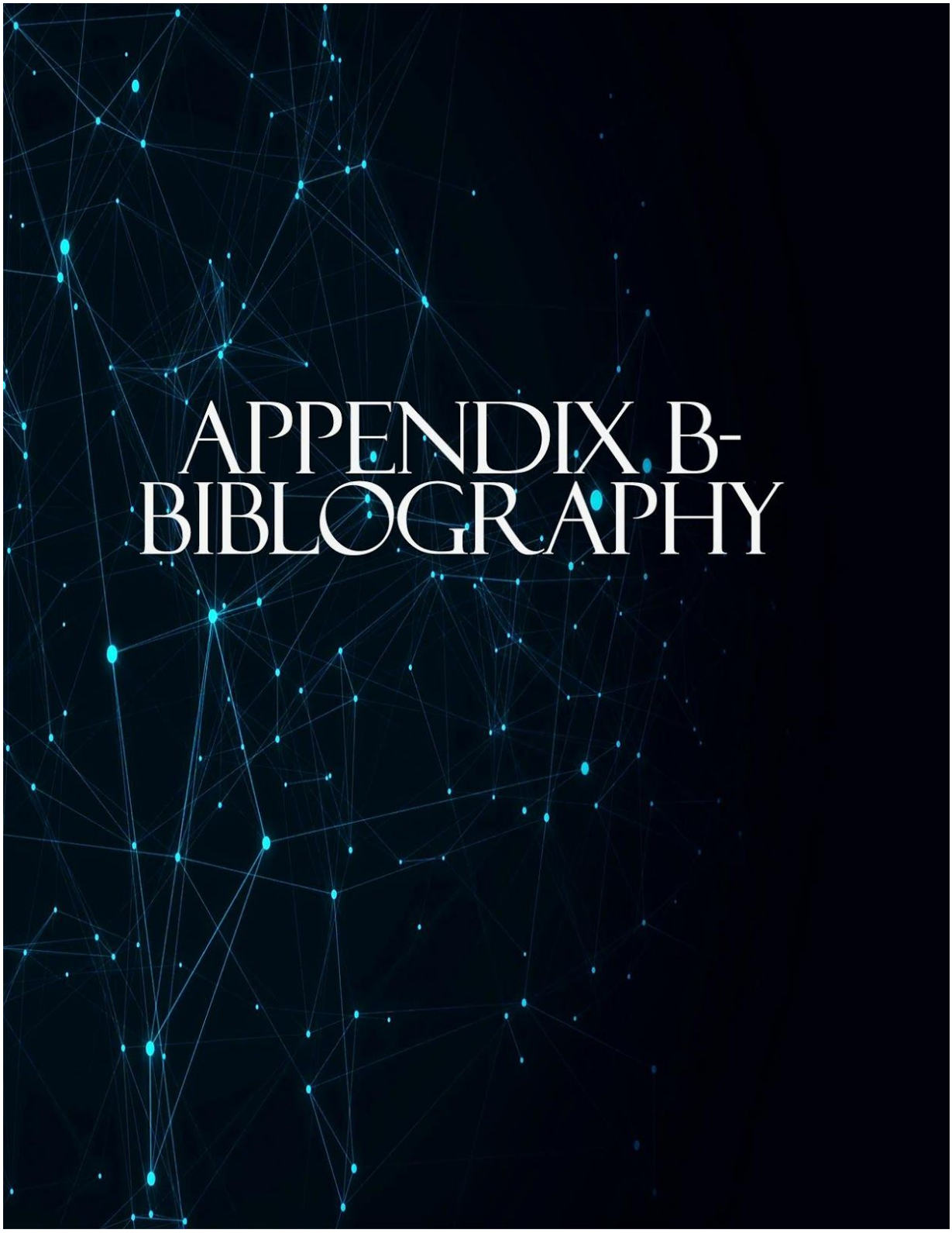
28th January 2038
Acasal, Day Three

Lara: Even with the same day-night cycles as Earth, time seemed to fly in Acasal. I can't believe it is our last day already.
Stephen: Well, we will always have an excuse to come back, whenever we want to visit Earth.
Arya: I will miss the beautiful views here. I mean, looking at the Earth above and Moon below, it's beyond my wildest dreams. But sometimes reality can be more beautiful than a dream.
Nat: I will miss all the fun activities we did here. But Dad, there is one more left, right?
Stephen: Yes there is the Rocket Football League. We are also yet to take a tour of Singularity.
Nat: Is it anything like our old-school football?
Stephen: It is similar, you can say. Except that you have five more surfaces to play on, and you're seated in a vehicle.
Arya: What? What type of game is that?
Stephen: You will see for yourselves in a while!

(Rocket Football Stadium)
Nat: Dad, what made you think this was similar to our football? This is a crazy times more amazing!
Arya: I cannot wait to play this.
Stephen: Yes it's more intriguing and rather, less exhausting. But it requires a good control on the vehicle. There are magnetic systems in the vehicle which allow it to drive on walls, so it is like three-dimensional football, if our conventional football is considered planar. Let's go try it out!

(Singularity)
Stephen: This is the last part of our Acasal itinerary - Singularity. It is the name of the outer cylinder which houses most of the Acasal citizens. It is as Earth-like as it gets.
Arya: Does it also have a mall, like Dobby said?
Lara: It has many, many more facilities. It has a multiplex, a museum, a library and a school as well. You would actually like living here.
Stephen: I just love the look of houses here. I like how they go from 19th century art to contemporary to traditional houses.
Nat: I'm just sad. There's so much to do here and so much more to see.
Arya: I know, right? We've been in here for three days, but the very idea of Acasal is awe-inspiring.
Lara: It's a monument to the space program, a milestone for humanity, and kids, thank us later for emptying our pockets to get us here! I hope you'll remember our time here.
Stephen: From our first steps, sending monkeys and a dog into orbit, we've come so far. And yes, we expect you guys to pay us back in full when you're older.
Nat: Ooh, could we have a space pet? Please?
Lara: Shush (laughing). Rey and Leia are here to see us off. Let's go.

The family completed all the remaining formalities, and boarded their shuttle. LEX brought the CASSSC containing their belongings to the port, and REX loaded it onto the lunar shuttle. Their time had Acasal had come to an end, but Acasal would remain- an oasis for thousands of more families to come. Acasal, as an idea, a home, and a community, stood that day as one of humanity's most intricate works of art, in the more general sense of the word, and will continue to be a beacon, leading mankind into the future.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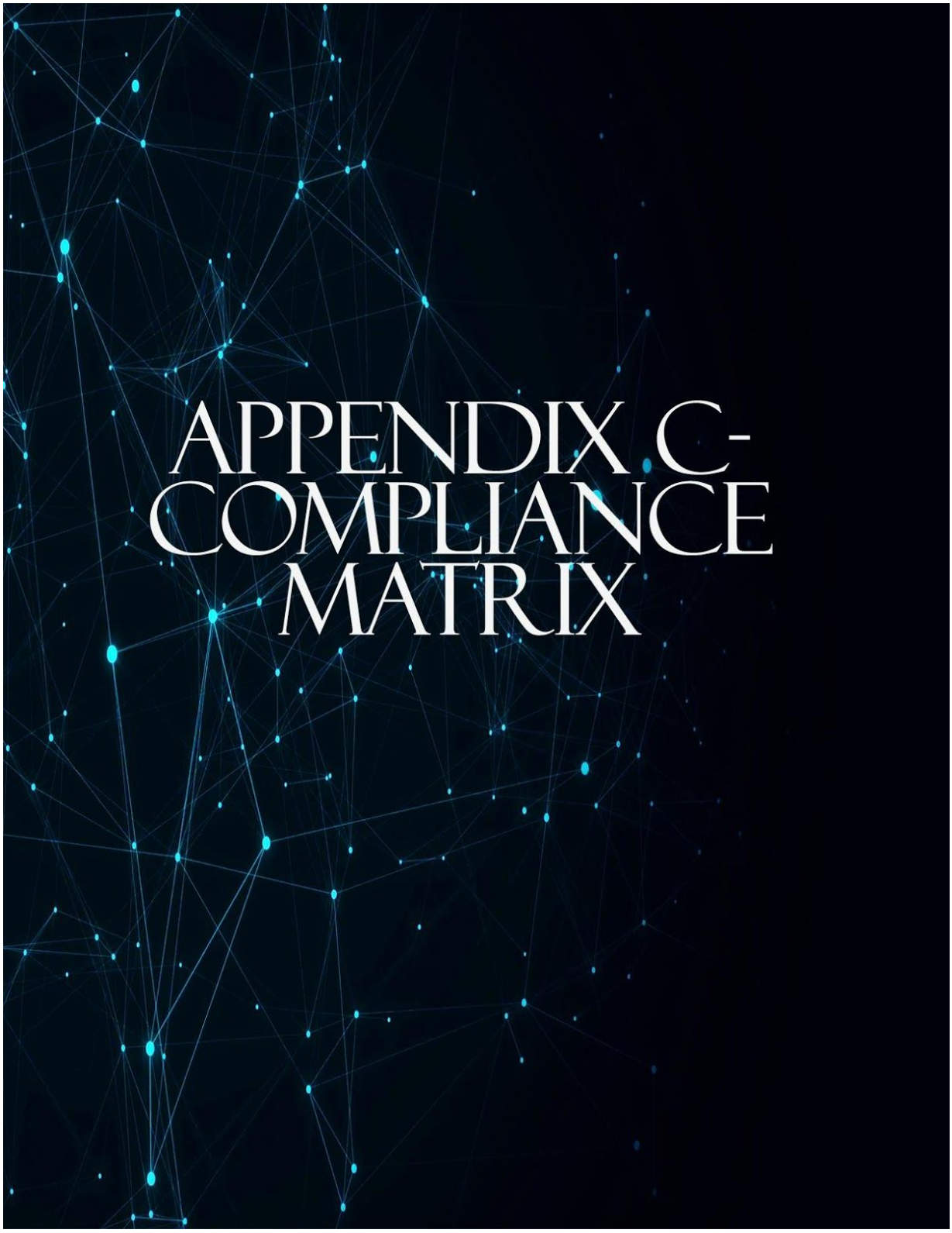
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