COLUMBIAT

Team Ignite - Mumbai

7th Indian National Space Settlement Design Competition
Team Data Form

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

Name [gender](grade/age)

Shiv Kini	[ ](11/16)	Mokksh Shah	[ ](11/17)
Ninad Atale	[ ](12/17)	Hrishita Shah	[F](12/18)
Viraj Aggarwal	[ ](12/17)	Anisha Goyal	[F](9 /14)
Kcavyan Agarwal	[ ](10/15)	Taher Kachwala	[ ](9 /14)
Hridank Garodia	[ ](10/15)	Sachchit Jha	[ ](12/17)
Vidit Bhimrajka	[ ](11/16)	Kavish Mistry	[ ](12/17)

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

Chetan Kini	[ ]	Priyanka Atale	[F]

I understand that if **our** team qualifies for the Indian National Space Settlement Design Competition in November 2023, we will be expected to finance our own travel to / from Om Shanti Retreat Center, Manesar and share the cost of boarding / lodging during the competition.

Signature of primary chaperone/advisor

31-10-2023
Date

1.0 EXECUTIVE SUMMARY

Columbiat represents a bold endeavor into the boundless expanse of space, envisioning a pioneering leap for humanity towards the final frontier. With meticulous attention to detail, Columbiat embodies the core values of seamless operational efficiency, prioritizing a nurturing living and working environment, and an unwavering commitment to pushing the boundaries of human potential.

Deliberately chosen materials for the hull and windows of Columbiat underscore our paramount concern for the safety, security, and structural robustness of the vessel and its inhabitants. These choices ensure protection from cosmic debris and radiation, while guaranteeing unparalleled tensile strength. Moreover, the integration of solar panels within the hull, combined with the utilization of lunar materials, establishes an economically viable settlement, offering a sustainable and plentiful source of energy and materials for future maintenance and expansion.

Columbiat's comprehensive residential and community plans epitomize an ideal settlement design where seamless transportation, accessibility, and a sense of homeliness are prioritised. Our community settlements are intricately crafted to provide a luxurious living experience, akin to the comforts of life on Earth. The residential layouts are meticulously designed for both efficiency and ease of use. Notably, the introduction of an internal transport system ensures swift mobility and minimizes travel time, echoing the convenience of terrestrial living.

The construction process is meticulously optimized to minimize disruption to operating business operations, ensuring swift service availability. Our distinctive triangular design enhances transport networks while supporting the self-sustained, individual modules. This structure aligns with our settlement's primary objective of serving transport ships through expansive port facilities and cargo-handling services.

As the space's business capital city, our settlement offers a sprawling 209,000m² of office facilities, luxurious business hotels, and a cutting-edge stock exchange facility with a real-time digital trading platform. Furthermore, our 0-gravity area hosts a unique amalgamation of recreational activities apart from the compact, refined cargo handling and warehousing system.

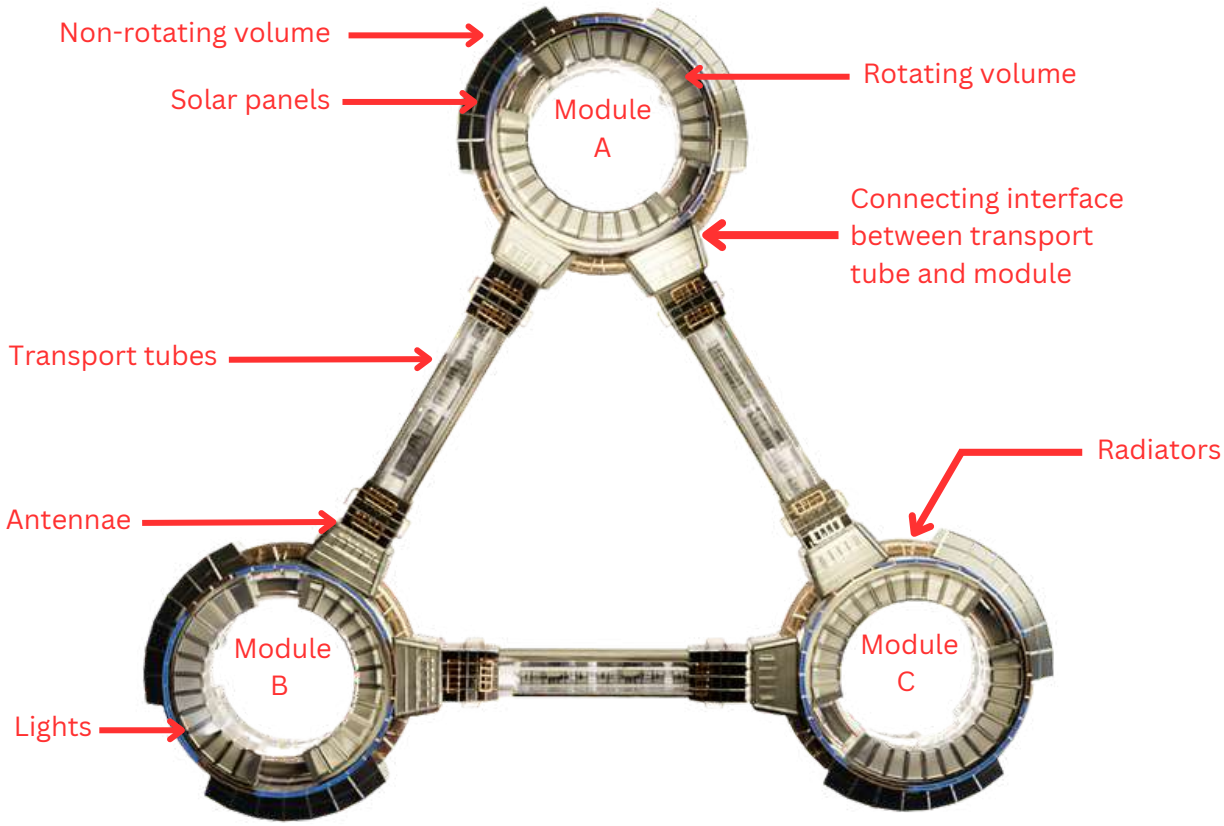


Figure 1.1: Major Structural Features [Made by Shiv K. in Blender]

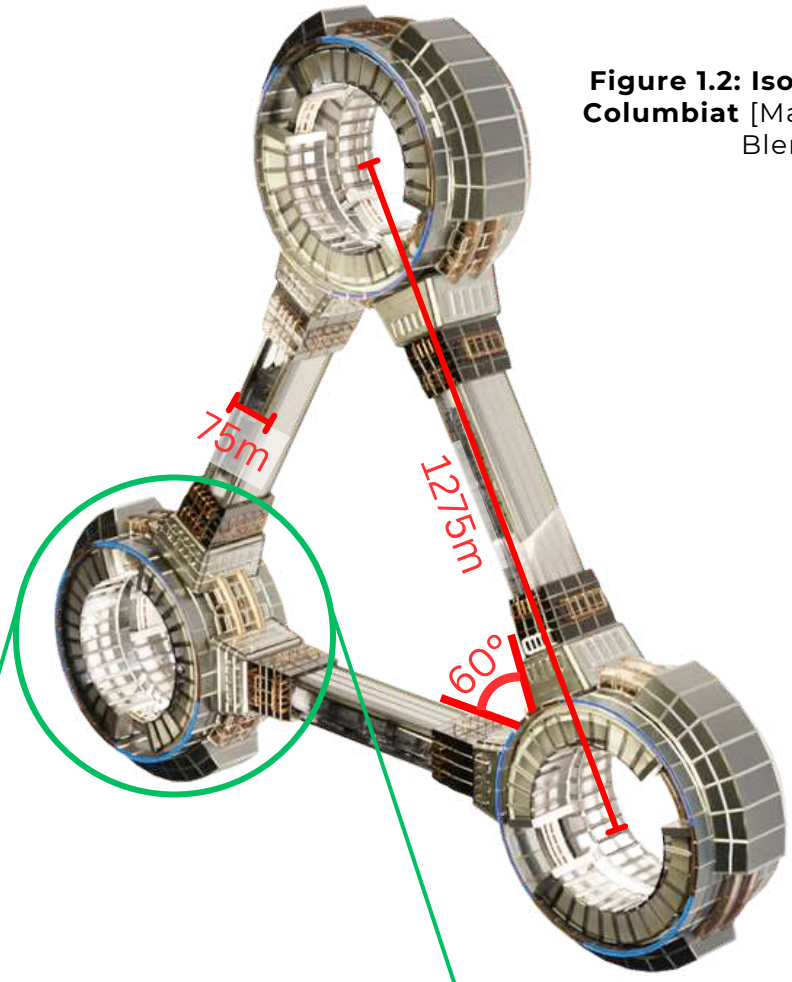


Figure 1.2: Isometric View of Columbiat [Made by Shiv K. in Blender]

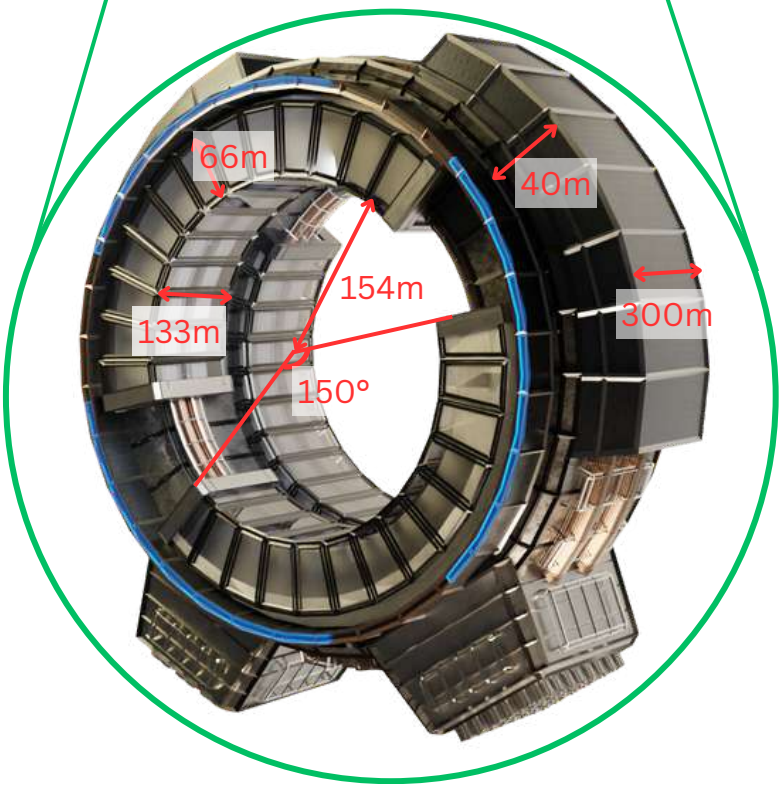


Figure 1.3: Per Module Dimensions [Made by Shiv K. in Blender]

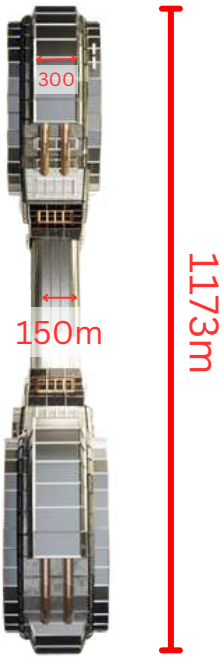


Figure 1.4: Side View [Made by Shiv K. in Blender]

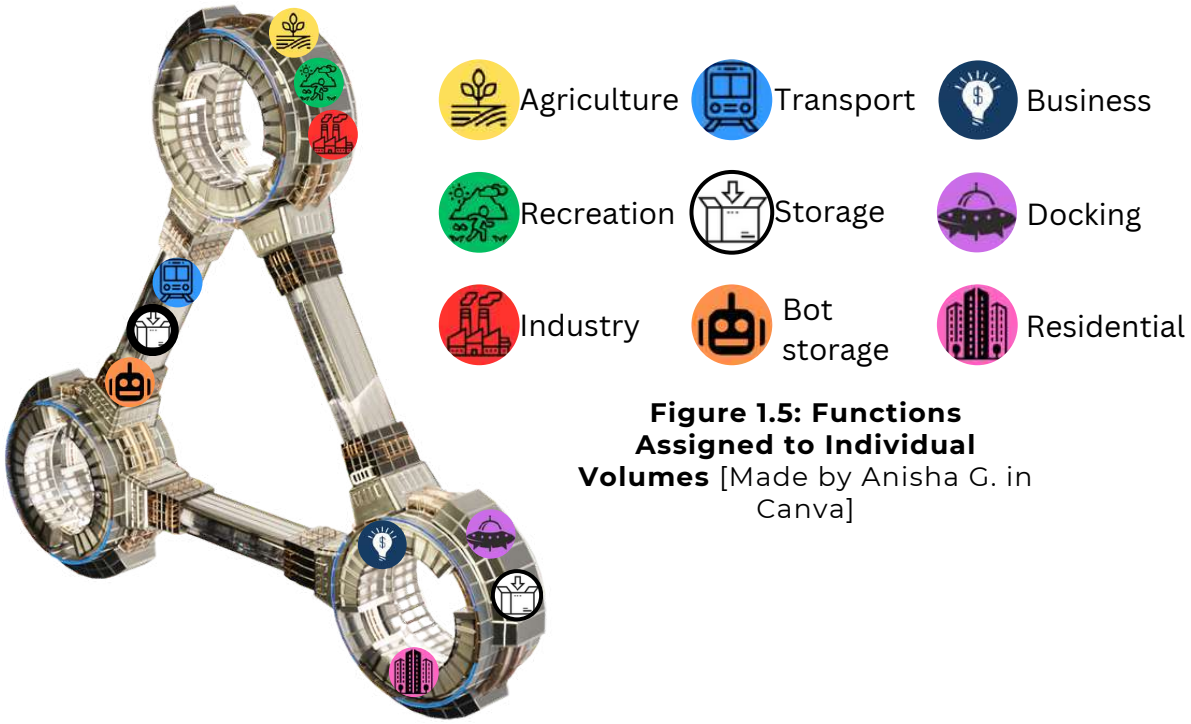


Figure 1.5: Functions Assigned to Individual Volumes [Made by Anisha G. in Canva]

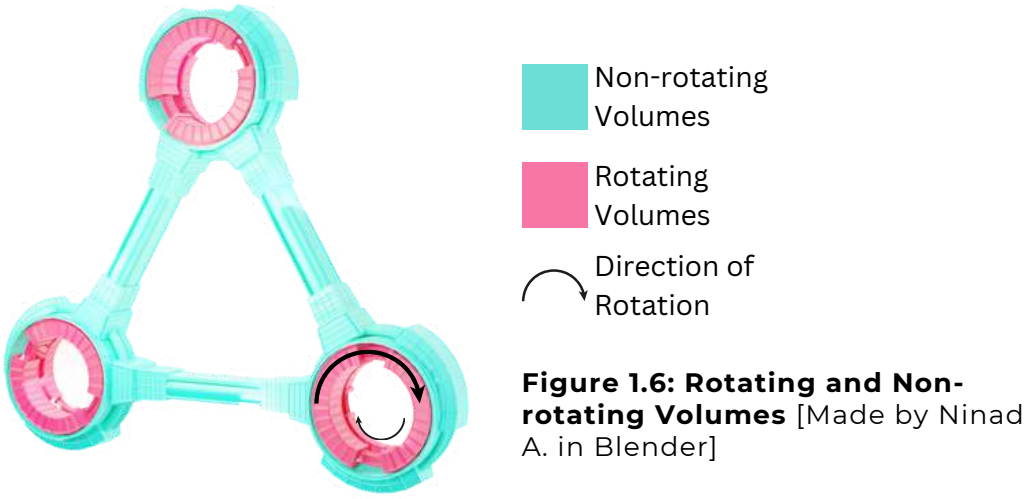


Figure 1.6: Rotating and Non-rotating Volumes [Made by Ninad A. in Blender]

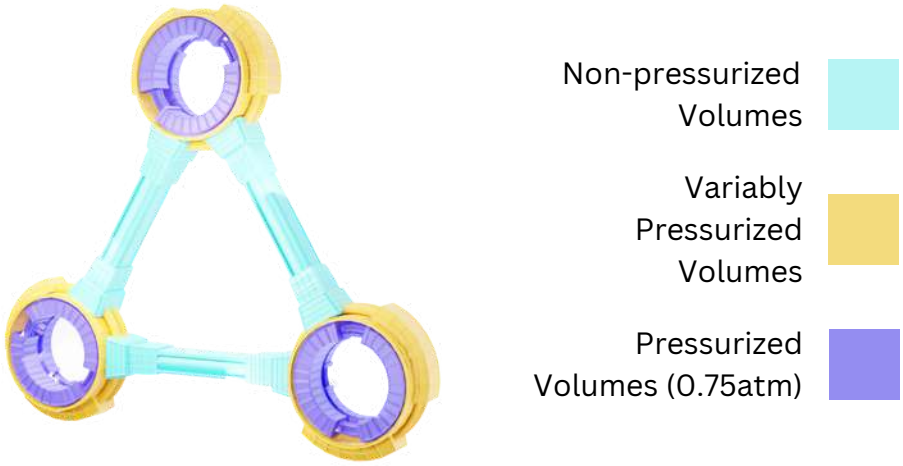


Figure 1.7: Pressuized and Non-pressurized Volumes [Made by Ninad A. in Blender]

2.0 STRUCTURAL ENGINEERING

2.1 External Configuration

Columbiat's structure provides an ideal amount of space and flexibility for its residents to live in and comfortably partake in service activities in the space economy.

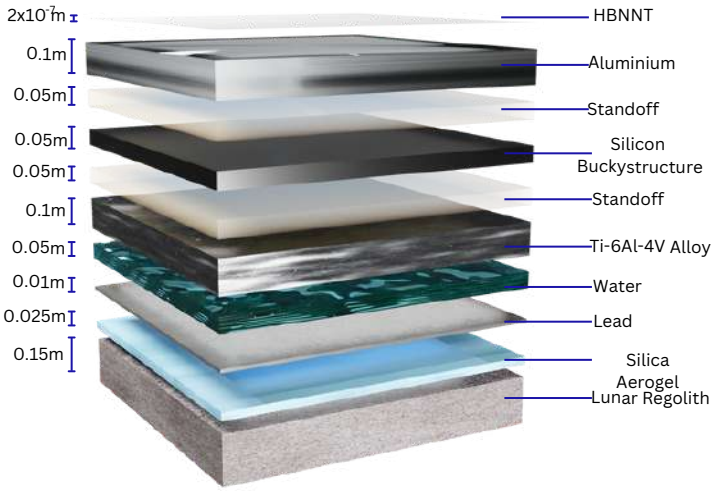
2.1.1 Uses of Large Enclosed Volumes

Completed, Columbiat will comprise three modules, arranged in a triangular formation and connected by three transport tubes (detailed in 3.4). Each module will have two sets of oppositely rotating 150° arcs, connected via a transport line and situated within a bi-bulged 0g ring as seen in figures 1.1 and 1.3.

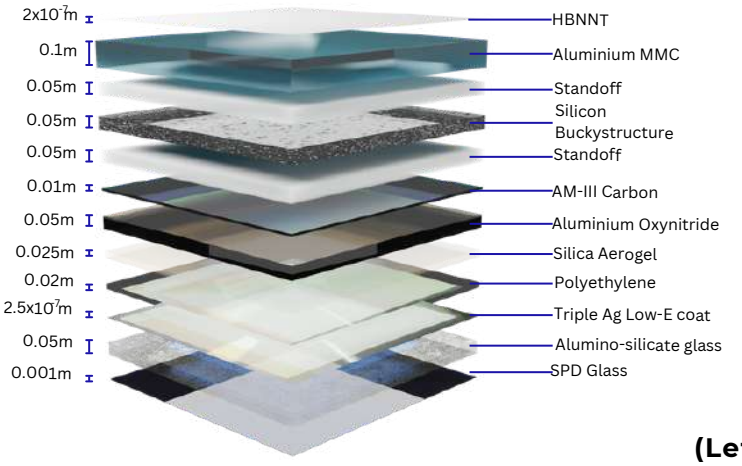
2.1.2 Materials

The materials selected for constructing the hull and windows are readily available on the Earth and the Moon. The lightweight, yet sturdy materials are affordable and suitable for transport. Alaskol and Alexandriat can synthesize materials such as Hydrogenated Boron Nitride Nanotubes (HBNNTs) or Low-emission coats. Using composites, metals, and nanomaterials together provides Micrometeoroid and Orbital Debris (MMOD) impact resistance, radiation protection from cosmic rays and solar flare events, and thermal insulation. Panels for both the hull and windows are curved and will have a length and width of 10m. The hull's thickness is 58.5cm and the window's thickness is 40.6cm.

The hull contains a tri-layer whipple shield with two layers of air to allow the debris cloud to expand. Hydrogenated BNNTs, Water, Buckystructure fabric and Lead provide adequate radiation protection. The placement of the nanotubes at the exterior prevents the development of secondary radiation due to neutrons. Hydrophobic silica aerogel provides a majority of the thermal insulation.



(Right) Figure 2.1.1: Hull Materials
[Made by Vidit B. in Blender]



The windows consist of a tri-layered whipple shield with air in between. The complete window has a visible light transmission (VLT) level of 0.6-0.7. The AM-III carbon provides immense impact resistance and has a Vickers number (VH) of 113GPa. A thin film of BNNTs, and the triple-silver low-emission coat provide adequate radiation protection. The Low-E coat is opaque to most wavelengths of ultraviolet and infrared radiation.

(Left) Figure 2.1.2: Window Materials
[Made by Vidit B. in Blender]

2.1.3 Artificial Gravity Levels

With a rotation of 1.8rpm, facilitated by the magnetoplasmodynamic (MPD) type thrusters attached on the free ends of the residential arcs. Columbiat simulates an artificial gravity of 0.8g at down surfaces by harnessing the centrifugal force experienced in the rotating frame. The outer ring in each module is at 0g.

Given that each module features a pair of counter-rotating sets of residential arcs (i.e. 4 arcs in total), Columbiat achieves stability, with gyroscopes on the outer ring allowing for minor corrections.

2.1.4 Air pressure maintenance on rotating interfaces

Columbiat will simulate artificial gravity by having the residential modules rotate internally against the outer 0g rings. The rotation of the modules will be supported by a series of ceramic ball bearings located around the outer circumference of either end of the modules.

The interface between rotating and non rotating components will be through the ColumBUS system (refer 3.4). Each module will have a station (mentioned in 3.4) which will act as a transfer zone from the rotating residential arcs to the non rotating 0g ring. In total, Columbiat will have 12 stations for transfer.

Each 0g ring will have 4 transfer openings for each module in order to maximize windows for transfer. Transfer will take place when the transfer window is initiated. A drawbridge will extend from the bus station and latch onto the tracks in the 0g tings with ball bearing ends such that it moves along the tracks as the module rotates. The bus then has a 12 second window to move down the drawbridge and onto the non rotating ring. After transfer is successful, draw bridge is retracted until next transfer window. The entire process occurs in an air tight region where air pressure is the same on both sides.

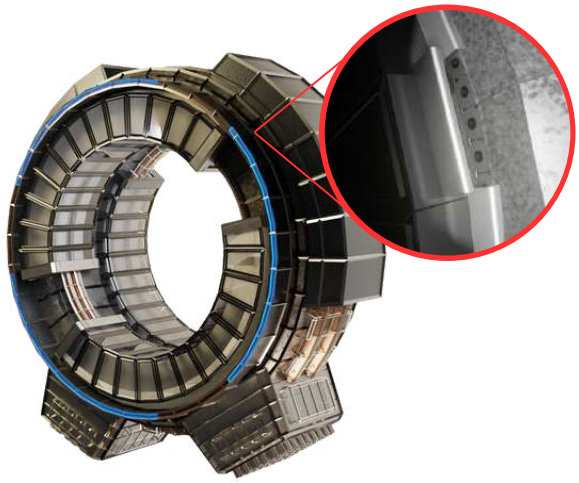


Figure 2.1.3: Locations of Bearings
[Made by Shiv. K in Blender]

2.1.5 Radiation and debris protection

Columbiat is positioned at L4, which has relatively less debris. However, hypervelocity impacts are a problem no matter what the Lagrange point is. Both the hull and windows contain tri-layered whipple shields to prevent micrometeoroid penetration or damage to the hull. The use of powerful aluminium-titanium alloys and aluminium composites could allow debris to not penetrate even through the first layer of the whipple shield. In the event of larger incoming debris, that is detectable and thus often greater than 10cm in length, redirection collisions or robots attempting to slow down the debris can be implemented.

Hydrogenated Boron nitride nanotubes provide protection from galactic cosmic rays as well as solar particle events, thus preventing the development of secondary radiation.

The use of lead, water, polyethylene and a Low-E coat block UV, Gamma, X-rays and infrared radiation. Regolith and the silicon buckystructure fabric provide secondary protective measures for scattered radiation after BNNTs.

2.2 Internal Layout

Columbiat consists of spacious, well-organized modules featuring generous down surface areas. The settlement accommodates all business functions along with fulfilling residential requirements by utilising an arc-like shape. This maximises the surface area to volume ratio, while still remaining resource-efficient. The design maximises on providing space for business development, without compromising on residential space.

2.2.1 Interior Down Surfaces

Columbiat offers a spacious living environment for its occupants, with the

residential arcs consisting of a down area exceeding 936,000m2. This settlement aims to maximise on the available area, while still straying clear of creating a disoriented layout, achieved by incorporating four arcs within each of the three modules. Each of these structures provides an interior down area over 76,000m2, as depicted in diagram 2.2.1 where further dimensions are given. The allocation of space within the residential arcs is strategically designed to centralise commercial areas, with business development constituting 45.5% of the overall residential area, the largest share by far excluding infrastructure. Residential housing was planned to accommodate an average area of approximately 35.5m2 per person

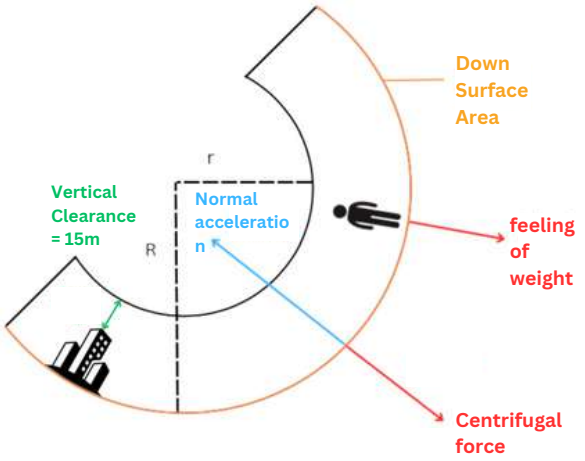


Diagram 2.2.1: Down Surface Orientation [Made by Anisha G. in Canva]

Further details regarding area allocations and usage can be found in table 2.2.2. Moreover, due regard has been given to zero-gravity areas, vital for facilitating business development, sanitation, and amenities. Enclosing each module is a ring comprising two large bulges, collectively covering an area exceeding 30,000m2. The flooring of this section was made parallel to the faces of the modules to integrate a majority of the available space. In the interest of optimizing resources, space, and labour, the zero-g ring was partitioned into two 90° arcs, each accommodating four floors. This configuration not only provides a systematic layout but also maximizes the down area, amounting to an estimated 120,000m2. Table 2.2.3 shows the down surface areas used by each department in both areas with gravity and areas without.

Usage	area/m2	% of g area
residential	200206	21.37
commercial	86598	9.25
utilities	19982	2.13
healthcare	17750	1.89
administrative functions	278650	29.75

Table 2.2.2: Down Surface Area allocations [Made by Anisha G. in Canva]

Dept.	g%	0g%	total %
Human Factors	47.87	0.00	37.66
Business Developm -ent	45.54	72.00	51.19
Automati o-ns	1.33	4.02	1.91
Operation -s	5.25	23.98	9.25

Table 2.2.3: Down Surface Area allocations [Made by Anisha G. in Canva]

2.2.3 Vertical Clearance

Each of the residential modules will have a maximum building height of 45m, providing a vertical clearance of 15m (Ref to diagram 2.2.1). The extra 6 meters will be utilised for an underground underground tunnel system, which would be a centralised

transportation system for the movement of goods through the settlement. With long lines of sight and the illusion of a horizon, issues like claustrophobia will be avoided. The docks will have a maximum building height of 30m, giving a vertical clearance of 45m.

2.3 Settlement Assembly

Columbiat will be constructed entirely in orbit, beginning with the establishment of a vessel, subcontracted to BlownAway, that will serve as a construction shack and base of operations. During construction, CASSSCs filled with materials will arrive here - to be stored on magnetized surfaces on the inflated vessel. Communication systems will also be set up and a foldable solar panel array will be deployed as an initial power source.

The construction of the main settlement will happen through the use of panels attached to a truss-based mesh, subcontracted to BeamBuliders, making both the construction and any future repairs easier. The construction sequence is divided into 3 phases, allowing for 14 steps overall.

Phase 1: Construction of Module A

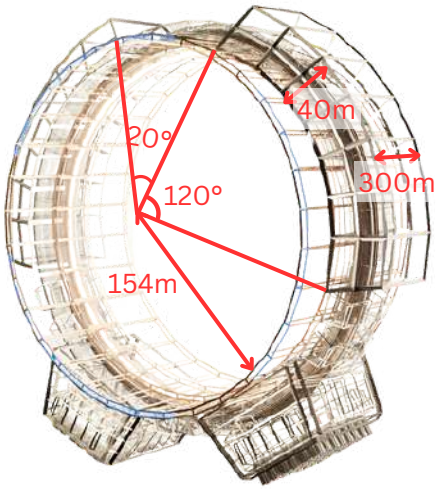


Fig 2.3.1: Step 1 [Made by Ninad A. in Blender]

1) Module A's construction begins from the outer zero-g ring. The Europa bot lays down the mesh to which the material panels will be attached later. This framework accommodates docks, rotational interface points and expansion points which will be developed in the future.

3) Internal construction in the zero-g ring starts. The internal wiring of the zero-g ring is carried out, subcontracted to Zap! Industries.

(Right) Fig 2.3.3: Step 3 [Made by Ninad A. in Blender]

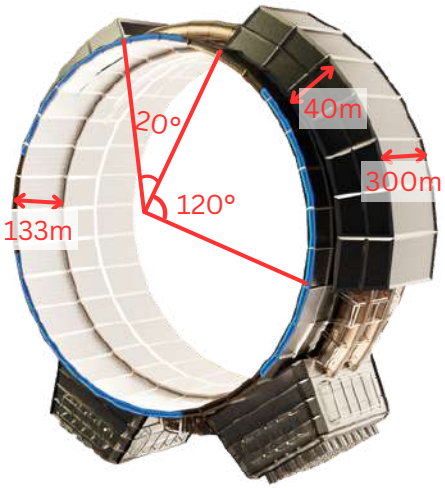
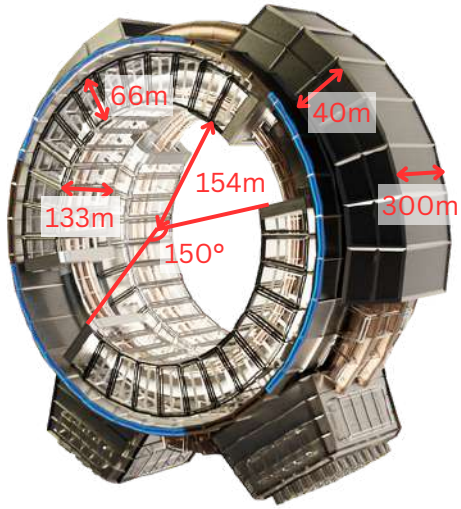


Fig 2.3.2: Step 2 [Made by Ninad A. in Blender]

2) The Europa bot now begins laying panels on top of the mesh, bending them to match the curvature of the settlement. The construction of one bulge is completed first and the docks are made operational.



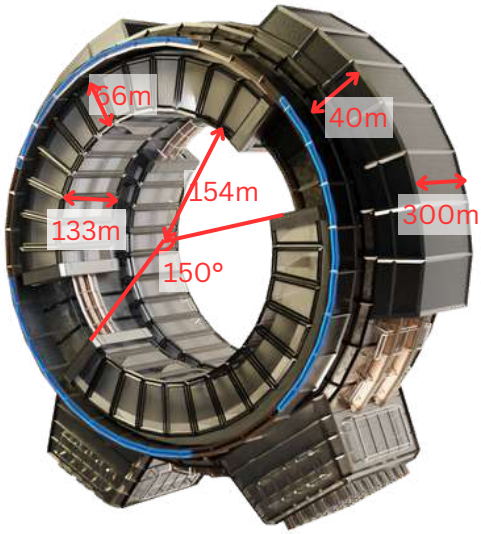


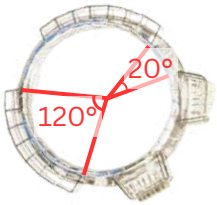
Fig 2.3.4: Step 4 [Made by Ninad A. in Blender]

4) The wireframe mesh for the rotating arcs is connected to the zero-g ring using the rotational interface, completed by the Europa bot. The bot now lays panels, that it curves and assembles, on the rotating arcs.

5) Upon completion of step 4, the internal construction bot works on the interiors of the residential arcs. Nanobots, subcontracted to nanosolutions, seal gaps between all panels on the settlement using Kalrez 7075.

6) Thrusters, gyroscopes and radiators are added and pressurization checks are completed. Rotation begins and the module becomes functional with 0.8g gravity in the residential areas.

Phase 2: Construction of Module B and its Connection to Module A



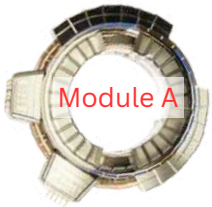


Fig 2.3.5: Step 7 [Made by Ninad A. in Blender]

7) Module B's construction begins with a wireframe, just as in the case of module A. The wireframe is laid out by the Europa bot in the place where module B will be positioned relative to module A

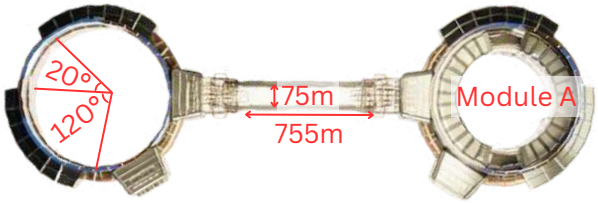
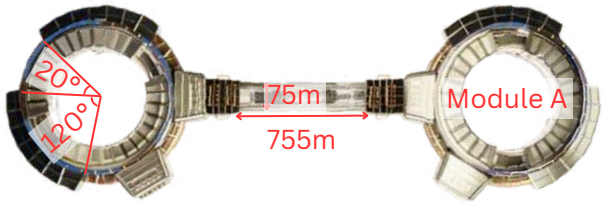


Fig 2.3.6: Step 8 [Made by Ninad A. in Blender]

8) A set of Europa bots begins laying the framework for the transport tube needed to connect modules A and B together. The tube starts from the non-pressurised expansion point of module A to the same point on module B.

(Right) Fig 2.3.7: Step 9 [Made by Ninad A. in Blender]

9) Panels are laid on top of the connecting transport tube by the Europa bot as module B's construction continues. The connecting tube is connected to the interface on module B.



10) Module B is completed and pressurized, in the same way as module A.

Phase 3: Construction of Module C and its connection to modules A and B

11) Just as in phase 2, the wireframe of module C is laid out in parallel with that of its connecting tubes. (See fig 2.3.8 on the next page)

12) The module is connected via expansion points to the connecting tubes after the panels have been laid on them.

13) The construction of Module C is completed and tested in the same way as module A.

14) Columbiat begins to operate at full capacity (See fig 1.1 in executive summary).

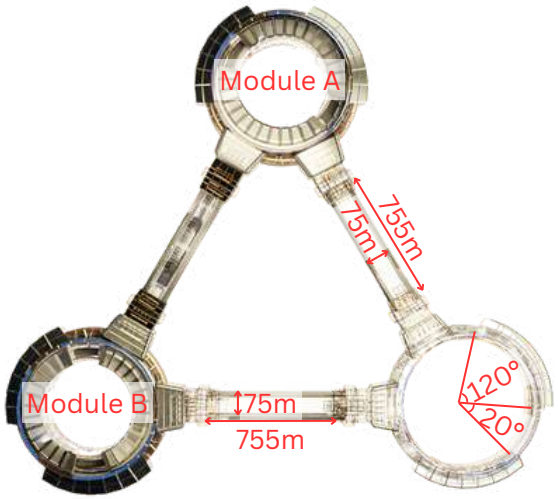


Fig 2.3.8: Step 11 [Made by Ninad A. in Blender]

2.3.2 Repurposing of CASSSCs

Through deliberate and resource-conscious strategies, Columbiat aims to leverage CASSSCs in multiple facets of our operations, ensuring efficient utilization. In line with this objective, we have implemented strategic approaches to maximize the utility of CASSSCs.

One of the ways that we have repurposed these containers is to retain their original purpose of serving as standardised cargo storage. Within our repair centre, emptied CASSSCs are repurposed as storage units. These units accommodate various items, including parts of the settlement robots, general parts for vehicles that are entering the settlement, and parts ordered for repair. This approach ensures optimal utilization of these containers while minimizing waste.

In our commitment to safety, Columbiat prioritizes the provision of evacuation pods. To this end, we have repurposed CASSSCs to create 1250 escape pods, as shown in fig 2.3.9.

To maximise the use of these invaluable containers, and reduce waste as much as possible we're also integrating the material in the space suits.

Furthermore, the significant size and abundance of CASSSCs make them an ideal resource for our recreational facilities and a substantial portion of our furniture. By incorporating CASSSCs into these areas, we optimize their usage and reduce the need for additional resources.

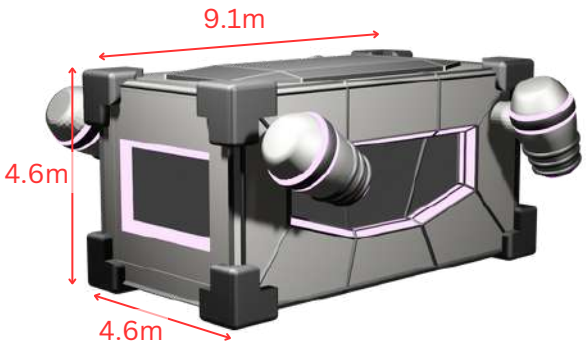


Fig 2.3.9: Escape Pod [Made by Vidit B. in Blender]

2.4 Accommodation and designation of business functions

As mentioned in section 2.1, Columbiat comprises three modules arranged in a triangular formation.

Columbiat will comprise of 3 modules each rotating at 1.8rpm on its own axis. They will each consist of 2 outer arcs that do not rotate on their own axes, thus allowing for 0g areas. 0g areas have been allocated to transport facilities, recreation, manufacturing, etc. Business functions have been divided into transportation and port servicing; finance, tourism and commerce; and space governance & legal and defence. Transportation and port servicing has been divided into docks, terminal facilities, refuelling and maintenance, repair and operations (MRO). Finance, tourism and commerce is extended to offices, banks, stock exchanges, foundation society headquarters, recreation. Space governance requires the construction of embassies, garissons courts, offices and control centres. Garrisons will be present in all 3 modules.

2.5 Process of Initiation

As detailed in section 2.3, each of Columbiat's modules are individually made operational (as per the schedule in section 6.1) and business functions migrated between them.

2.5.1 Procedure for migration of business functions

Legal, Business and transport functions will all be operational in each stage of construction, serviced in varying capacities by each of the three modules. All equipment specific to a particular function will be transported in CASSSCs while the structures allocated to those functions will be repurposed.

Transportation services including refuelling, terminal facilities, port servicing companies and docks (Refer to section 7) are all equally split among the three modules, given that the main purpose of this settlement is for transportation.

Finance and Commerce functions will be concentrated around module B. These functions include offices, banks, stock exchanges, foundation society headquarters and some recreation services. To prioritize bank and stock exchange functions, a majority of the infrastructure being set up when Module A becomes operations will cater to these needs. The community plans are given in figure 2.
Government and defence services comprise courts, embassies, garrison, and control centres. Since the control centres are one of the first things that will need to be made operational, they will be concentrated in module A and connected to the rest of the settlement later on. Embassies are the next most important services to provide which is why they will be accommodated in module B. All other business functions in this division will be developed in module C.

Transport			
	A	B	C
Module A built	100	-	-
Module B built	50	50	-
Module C built	33.33	33.33	33.33
Business			
	A	B	C
Module A built	100	-	-
Module B built	40	60	-
Module C built	30	60	10
Legal			
	A	B	C
Module A built	100	-	-
Module B built	80	20	-
Module C built	30	10	60

Table 2.5.1: percentage of tasks/functions being accommodated for by each module [Made by Anisha G. in Canva]

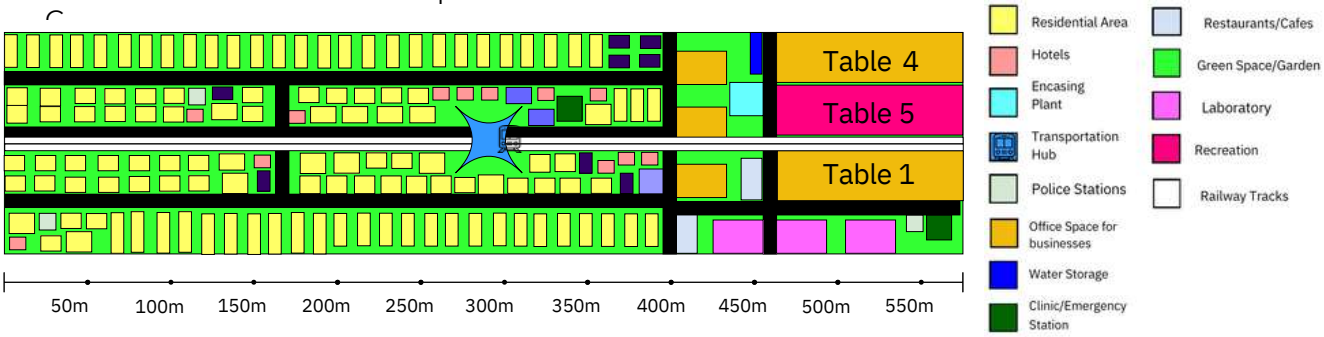


Figure 2: Community Plans [Made by Anisha G. in Draw.io]

3.1 Construction materials

Material	Volume/m3	Source
BNNT	5.38	Boron from Earth, synthesised by Alexandriat
Standoff	1563620	Air (Stuff of Life)
Aluminium	2550100	Earth
Silicon buckystructure	1337200	Carbon Creation
Water	1269500	Stuff of Life
TiAlV alloy	2544200	Alaskol to mine Aluminium, Titanium and Vanadium from moon
Lead	255900	Earth
Aerogel	668000	Alaskol to produce aerogel from silica on the moon
Regolith	3809700	Alaskol mining on moon
Aluminium MMC	125000	Earth, synthesised on Alexandriat
AM-III Carbon	12400	Earth
Aluminium Oxynitride	61700	Earth and Moon
Polythylene	25000	Earth
Alumino - Silicate glass	61600	Moon, mined by Alaskol
SPD Glass	1250	Earth

Table 3.2.1: Construction materials [Made by Vidit Bhimrajika on Canva]

3.2 Community Infrastructure

3.2.1 Atmosphere and Climate

Liquified Air will be supplied in CASSSCs from the Subcontractor Stuff of Life in regular shipments every 2 weeksSince Stuff of Life will be supplying air and not individual gases, each outer 0g region of each of the 3 structures of Columbiat will have an air separation plant. CASSSCs will be transported from docks to the air separation plant through the xxx transport system.

At the separation plant, cryogenic vacuum pumps will attach to the CASSSCs and extract the liquified Air.After air is extracted, the separation process begins.
Separation will happen in 3 columns dedicated to separation of one gas each. In the first separation column temperature will be maintained at -196°C (boiling point of Nitrogen). At this temp, Nitrogen will be separated from the liquified gas and will be collected at the top of the column.Remaining liquid gas is then pushed to the next column with temp maintained at -183°C to separate out Oxygen. In the final column temp is maintained at -78°C to separate out CO2 gas.

Gases after separation will be either moved into the Air Composition Control System (ACCS) or stored in CASSSCs in case of emergency. The ACCS will be used to maintain the optimum air composition required in each part of the settlement. The ACCS is a highly sophisticated network of pipes, dispensers, sensors, absorbers and Air Storage tanks. The optimum Air composition for the different parts of the settlement will be pre-fed to the ACCS. It will use its sensors to detect air composition changes and will adjust them via its dispensers and absorbers. In the case where excess of a gas is present, absorbers will be used to absorb the excess air. In case there is deficiency in a particular, that gas will be transported from its Gas Storage tank through the ACCS pipes and will be dispensed by the dispensers in that region until the optimum Air composition is met. These sensors, absorbers and dispensers will be placed strategically throughout residential, agricultural and industrial areas.

Air Composition in different parts of the settlement have been mentioned in the table below:

Gas	Residential Area	Agri-Zone	Industrial Area
N2	78.5%	73%	78.5%
O2	21%	20%	21%
CO2	0.05%	6%	0.05%

The temperature of the settlement will be maintained at 22 - 26° celcius with the help of fluid loop thermostats, distributed throughout the residential areas. Humidity will be maintained at 35% using humidifiers and dehumidifiers also placed at regular intervals throughout the settlement.
XXXX CASSSCS of air will be delivered to the settlement before Residency is achieved. The following shipments of Air that are delivered every 2 weeks will be used mainly in the ACCS to maintain air composition and a small part will also be stored after separation in case of emergency.

Initial No. of CASSSCs: 5700
CASSSCs of Air Delivered every 2 Weeks: 220

3.2.2 Food Production

In order to cater to the food requirements of Columbiat's population of 50,000, Columbiat will have a vast and diversified system of food production and supply both within the settlement as well as external sources.
Though Columbiat will have a vast collection of food options, major food items, their quantities and sources have been mentioned in the table below. Columbiat's food production and sourcing strategy is designed to ensure self-sufficiency and meet the dietary needs of its inhabitants, while also incorporating provisions for shipments from Earth.

3.0 OPERATIONS ENGINEERING

Within Columbiat's three major structures, specifically the 0g outer ring of each, an Agri-Zone will be established to address a significant portion of its food requirements. The Agri-Zone is subdivided into three distinct areas:

The Crop Cultivation Centre (CCC): The CCC specializes in the cultivation of fresh produce, utilizing advanced aeroponic systems, subcontracted to Garden-a-go-go.

It is important to note that the CCC exclusively focuses on the cultivation of fruits and vegetables amenable to aeroponic growth. Harvesting will be done by personnel provided by Garden-a-go-go. Fruits and vegetables that grow on trees will be sourced directly from Earth.

Food shipments from Earth will be conducted every 2 weeks. Shipments will contain **essential items such as grains, sugar, salt** and a portion of the total supply of **meats**, and various other food items, depending on the current inventory levels within Columbiat.

Grains from Earth will be delivered to both the Packaging and Processing Centre (PPC) and a dedicated seed bank within the Agri-Zone, serving as a safeguard in case of emergencies.

The Stem Cell Culture Centre (SCCC): The SCCC is responsible for the production of meats, milk, and dairy products.

*All values given below are in Kilograms (Kg)

Category	Source	Amount per person per day	Amount Required for Columbiat per day - 50,000 people	Amount required for Columbiat per month	Redundant Quantity for emergency produced per month	Total Produced / Sourced per month	Amount Produced within Columbiat per month	Amount Sourced from Earth Per Month
Meat	Trout	0.04	2000	60,000	9,000	69,000	34,500	34,500
	Pork	0.04	2000	60,000	9,000	69,000	69,000	-
	Beef	0.04	2000	60,000	9,000	69,000	34,500	34,500
	Chicken	0.04	2000	60,000	9,000	69,000	69,000	-
Produce	Eggs	0.024	1200	36,000	5,400	41,400	41,400	-
	Milk	0.5	25000	750,000	112,500	862,500	600,000	262,000
Dry Plant Produce	Wheat	0.18	9000	270,000	40,500	310,500	-	310,500
	Rice	0.1	5000	150,000	22,500	172,500	-	172,500
	Sugar	0.1	5000	150,000	22,500	172,500	-	172,500
Vegetableand Fruit	Carrots	0.1	5000	150,000	22,500	172,500	172,500	-
	Lettuce	0.1	5000	150,000	22,500	172,500	172,500	-
	Peas	0.15	7500	225,000	33,750	258,750	258,750	-
	Apple	0.1	5000	150,000	22,500	172,500	-	172,500
	Potato	0.1	5000	150,000	22,500	172,500	172,500	-
	Tomato	0.1	5000	150,000	22,500	172,500	172,500	-
	Orange	0.1	5000	150,000	22,500	172,500	172,500	-
TOTALS		**1814**	**90700**	**2,721,000**	**408,150**	**3,129,150**	**1,969,650**	**1,159,000**

Table 3.2.2: Food Quantities [Made by Shiv Kini in Google Sheets]
(Estimates made based on 1975 NASA Summer Study)

Given the substantial demand for meat, the SCCC will initially produce 50% of beef and fish through stem cell culturing, with the remaining 50% sourced from Earth. As Columbiat continues to expand, the proportion of in-house meat production will progressively increase. For rabbit and chicken, **Garden-a-go-go** will primarily handle production, although the SCCC can provide supplementary support as needed.
The SCCC will also feature a dairy unit, utilizing dairy proteins to generate synthetic milk and milk-based products via stem cell culturing of dairy proteins.
Synthetic milk produced on-site will serve as the primary source of dairy products within Columbiat, though natural milk will be sourced from Earth to accommodate the preferences of those who favor it.

Packaging and Processing Centre (PPC): The PPC is strategically located in close proximity to both the SCCC and CCC within their respective 0g rings. Its core responsibilities encompass the processing of food materials generated in the SCCC and CCC, as well as the efficient packaging of these products for distribution. The transport systems for 0g, as well as designated residential areas as outlined in section 3.2.x, will facilitate the delivery of food from the Agri-Zone in the outer 0g rings to restaurants and households throughout Columbiat.

3.2.3 Electricity Generation

Commodity	Power Requirement (KW)
Bots	1550
Household items	21875
Recreational Means	500
Communication	232 750

Table 3.2.3.1:
Electricity Consumption
[Made by Kavish M in Google Docs]

The settlement will use solar cells that will be on the **outer exterior ring** . They will produce 1.32 kilowatts per day per meter square. The solar cells will be made of plastic polymers which will be made of dye coated plastic which absorbs rays of the sun maximizing efficiency. 28,982 m2 of solar panels will be there producing a total of 38,257 kW on a normal day.
To completely maximize our efficiency levels, microbial fuel cells will be used in the settlement. Microbial fuel cells use human urine and waste with chemical energy to generate electricity. Microbes(refer 3.2.4) feed on the waste as their daily metabolic practices which forms excess electrons and when connected to a cathode generate a current, this will produce 0.3 MW a day.

Liquid fluoride thorium reactors will be 2 fluid reactor which will convert thorium to uranium releasing large amounts of energy. This will result in a production of 23,450 kW of energy a day. The reactors will need 2 tons of fissile material(thorium) every 5 weeks.and these will be placed In the zero g sections of columbiat.

The heat produced by these reactors will be cooled by the ammonia-cooled radiators present which will wrap around the main reactors. The excessive energy produced by these sources will be stored in the Sodium - ion batteries which will be present in the manufacturing section. The electrical grids and wiring of magnesium diboride cables will be subcontracted to **ZAP! Industries**

Commodity	Power Requirement (KW)
agriculture	5000
Manufacturing	15 350
processing	7850
electrochemical glass	4000
lighting	60
total	288935

3.2.6 External Communications

Deep Space communication will be established by a Quantum Entanglement Relay System(QERS). To transfer data from Earth to the L4 Libration point.Quantum Relay Station will be placed on the outer rings of Columbia. QERS has two optical terminals – a receiver and a transmitter. Highly modulated laser signs are transmitted via low-divergence light beams by the relay's optical modules, with all nodes in the system linked by the quantum key distribution which provides encryption. The InfraRed Delivery (TBIRD) system will be connected to a CubeSat based satellite constellation providing data transfer speeds up to 250 Gbps. The base structures on Columbiat for the QERS will be subcontracted to OrbitLink Communications.
In the time where the moon is blocking the path of the waves, other satellites, specialized CubeSats with QERS will act as a 'bridge' to relay the data to Earth.

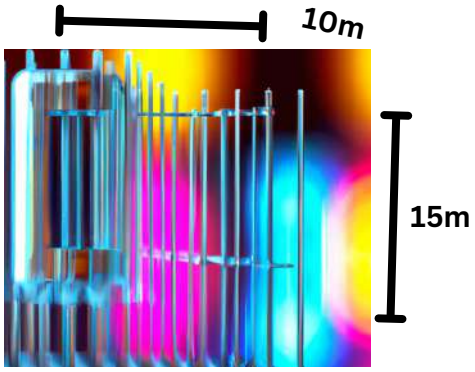


Fig 3.2.6: Quantum Relay Devices[Dall E]

3.2.7 Internal Communications

Internal Communications will be facilitated by Rowley - an antifragile quantum-based architecture. Rowley will provide internet services to the station for business, scientific and administration operations, ensure low-cost data storage, instantaneous and secure financial transactions and continuous agglomeration by central AI systems for healthcare monitoring and accident prevention. A scaled-down version of traditional QERS, Rowley will allow up to 1.2 Gb of data being transferred every second and be linked personally to each resident via their ring PCD

A modular system will be set-up to allow continuous updates and open source encouraged to allow customisation and setting-up of the necessary architecture for financial and industrial processes.

3.2.8 Waste management

Collection:
To collect household waste, Waste Stations will be built in every building. Here waste bags from dustbins are dumped. The Waste Stations would be lined with activated charcoal to absorb odours. These Waste Stations open up periodically into an underground conveyor belt, where waste would be conducted to the Encasing Plant. Here, it will be encased in High Density Polyethylene in 1m by 0.5m by 0.5 m containers. Next, these would be transported to Toss It To Me's waste plant.
To collect industrial waste, CASSSC's would be used. Waste would be packed in these containers, and be transported directly to the waste plant through the CASSSC conveyer belt. These containers would be primarily made with fiberglass reinforced plastic to provide strength, this material can also contain toxic waste. These containers will be lined with borated polyethylene which will stop the transmission of radiation from the waste.

Segregation:
To segregate industrial waste, every batch's pH and radioactivity levels will be measured, and thus be classified as 'Toxic' or 'Radioactive'.
For household waste, infrared spectroscopy would be done to separate inorganic matter from organic matter.

Treatment:
Household waste, specifically leftover food, will be composted in a high-pressure container at the recycling plant. The container will have a temperature of 300°C and will be emptied after every batch. The compost will be dissolved in water to make the nutrient solution for the vertical farms(reference to food). Waste products will be used to convert human waste into water and phosphorus. This phosphorus will then be added to the nutrient solution.
Bacteria would be added to toxic waste for the degradation and assimilation of small molecules in the mixture.
Waste that cannot be reused would then proceed to the landfills, where before entering, waste would be physically compressed, to reduce its volume before storage.

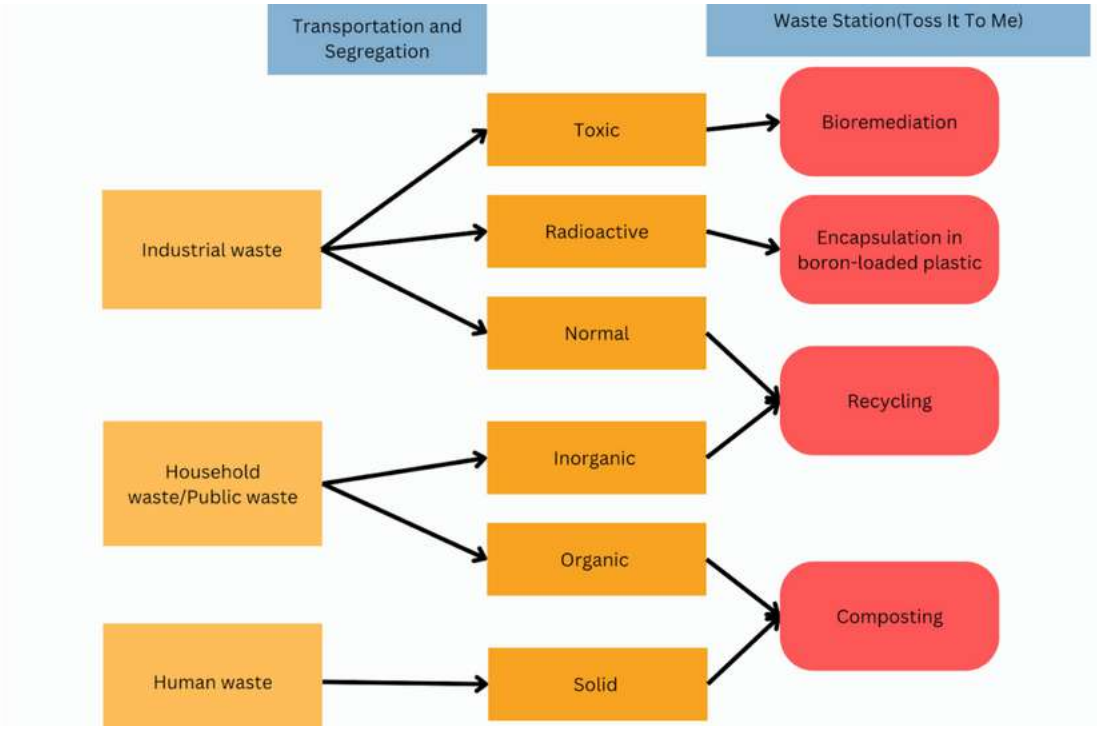


Fig 3.2.8: Waste flowchart[Made by Kcavyan Agarwal on Canva]

3.2.9 Water management

Hydrogel swells up without dissolving in water, while also providing a storage medium. To store these massive volumes of water, hydrogel pods would be used. The interior coating would be made of compressed hydrogel which is rigid when fully saturated. This adds strength to the container while also storing high volumes of water. These pods would be held together with fusion seals, saving space as and when water volumes decrease. 3 of these storage facilities will be present, 1 in each module's Resident Arcs.

Pipes will be used to distribute this water through modules in the settlement. For intermodular transport the water would be sent into the bus system. Piston pumps would pump water from the storage areas to the pipes.

1,00,00,000 liters of water will be subcontracted from Stuff of Life on a daily basis. This water will arrive on the docks and move to the hydrogel storage facilities through the CASSSC conveyor belts.

Fig 3.2.9: Water Storage system [Made by Canva AI generator]

Every day, the recycling plant will process 1,48,79,983 liters of water for recycling. The water recycling process will involve sequential steps, starting with nano filtration to remove impurities and contaminants. Next, bioremediation will be employed to destroy organic compounds in the water, followed by the use of ion exchange resins to remove any heavy metals that may contaminate it. After that, the water will undergo UV disinfection to eliminate microorganisms. Finally, carbon absorption will be used to remove any remaining contaminants.

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3.0 OPERATIONS ENGINEERING

3.3 Jigs and Fixtures

Hoberman Jig

This jig repurposes the cylinder jig (refer to 5.1.2 and 3.3). It uses the Hoberman mechanism to make objects of varying thicknesses for the exterior hull and the residential buildings. The jig can generate bolts, screws for small repairs, pins, rigid ventilation tubes, and pipes for water and sewage transport .

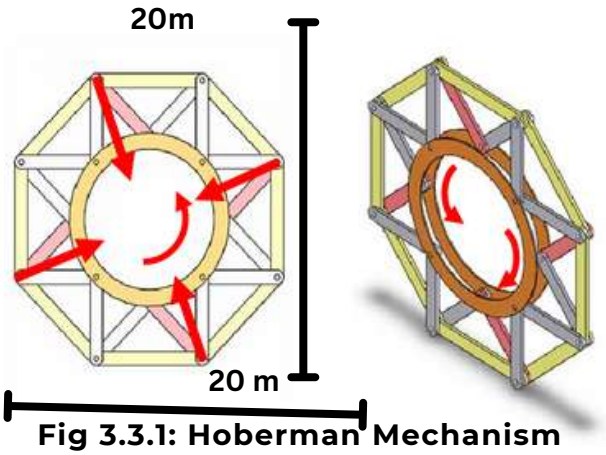


Fig 3.3.1: Hoberman Mechanism Jig [Semantic Scholar]

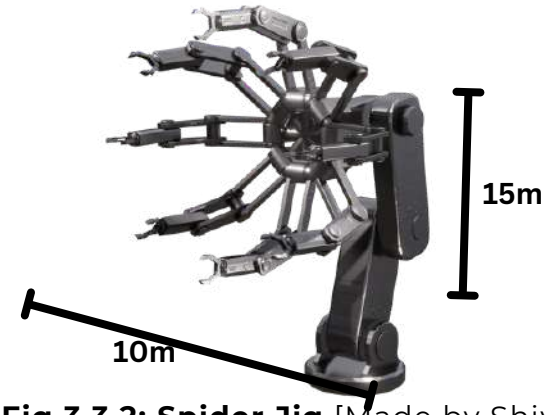


Fig 3.3.2: Spider Jig [Made by Shiv K in Software Blender]

Slider Rod Jig

he Internal construction bot 1 will have the extendable rods which will attach to the walls and then move up down to carry out its function.The rods again are stored near the storage unit on the construction bot and then it extends up, down and to the sides, they then attach to the walls and then accordingly move in all four directions smoothly transiting throughout the wall.

Commodity	Requirement/day/liters
Public	15,67,000
Residential	1,85,00,000
Industrial	784,322
Agricultural	1,876,000
Transportation (Cooling Systems)	257,000
Storage (Cooling Systems)	812,000
Maintenance	14,000
Research	834,000
Control Room	155,650
TOTAL:	24799972

Fig 3.2.9.1: Water Consumption [Made by Kcavyan A in google docs]

Spider Jig

This jig essentially employs the spider mechanism to assist the households with carrying out daily function.One can use the spider legs to attach the external construction bots to the metal using electromagnets and travel throughout the settlement.

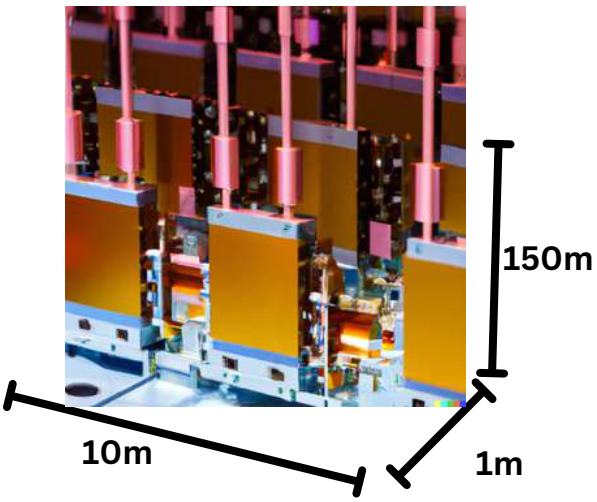


Fig 3.3.3: Slider Rod Jig [Dall E]

3.4 BUS SERVICE

Columbiat will have the ColumBUS system for transportation of people as well as packages within their respective modules as well as throughout the rest of the settlement. Each module will have a ColumBUS station where residents can get onto and off the Bus units. The ColumBUS stations also serve as transfer zones between rotating and non rotating parts of the settlement as elaborated in 2.1.4. ColumBUS will the main form of public transport throughout the settlement and will operate on tracks. Each ColumBUS unit will have 14 seats and will have the ability to link with other ColumBUS units. Furthermore, these units will be fully electric and will run on Lithium ion batteries. Each section of the settlement will have 6 zone specific ColumBUS units and 3 intera settlement units. Thus Columbiat will have 108 ColumBUS units operational at any given point with spare units in storage regions within the transport tubes for smooth transfer in case of failure of any ColumBUS units.

Fig 3.4.1: ColumBUS Station [Made by Shiv Kini]

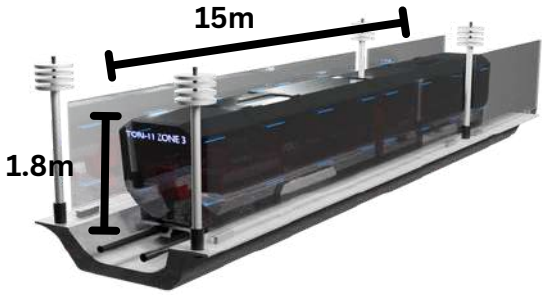


Fig 3.4.1: ColumBUS Unite [Made by Shiv Kini in Blender]

3.5 Changing functionality

Stage 2: *Operational Docks During:* the second stage, the settlement's docks become fully operational, primarily serving as the entry point for essential construction materials.

Stage 3: *Solar Energy Harvesting*: Following the successful installation of solar panels, the settlement starts the transition to a hybrid energy model that reduces reliance on external energy sources.

Stage 6: *Production and Infrastructure Readiness:* At this juncture, critical facilities such as the SCC and CCC start producing food. The settlement achieves pressurization and maintains a stable atmosphere. The installation of water and electric grids is completed, enhancing overall infrastructure. Additionally, an intra-module train system is introduced, facilitating internal mobility as the settlement welcomes its first residents.

Stage 9: *Solar Power Expansion:* As the settlement grows, additional solar panels are added to increase the settlement's capacity for independent electricity generation. This move marks a significant step towards self-sufficiency as more of the settlement's power needs are met through renewable energy sources.

Stage 10: Module B and Nuclear Energy: Module B becomes fully functional, hosting essential business operations. Simultaneously, the deployment of a nuclear reactor boosts energy independence to 90%, reflecting the settlement's commitment to sustainable energy practices and resource security.

Stage 12: Energy Autonomy Achieved: With the installation of the final solar panels, the settlement achieves complete energy autonomy, generating 100% of its energy internally. This accomplishment underscores the settlement's dedication to self-sustainability, resource efficiency, and responsible resource management.

Stage 13: *Food Production Autonomy:* In this phase, food production processes are finalized, resulting in complete autonomy in the settlement's food supply. The settlement can now sustain its population without relying on external sources for nourishment.

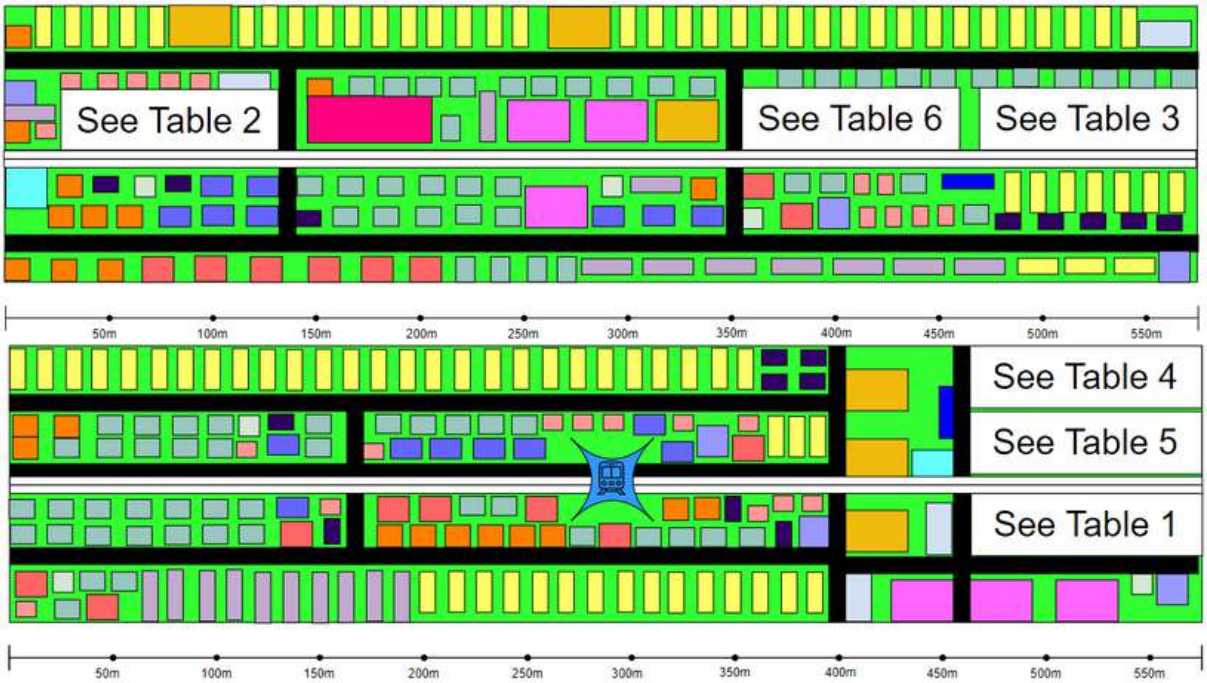
Stage 14: *Full Functional Viability*: At the final stage, the entire settlement reaches full functional viability.

4.0 HUMAN FACTORS AND SAFETY

4.1 Community Layout and Amenities

4.1.1 Community Designs

Where community maps refer to a table, the building in that area will vary in land use.



Mini 1BHK Condominium
Standard 1BHK Condominium
Standard 1.5BHK Condominium
Mini 2BHK Condominium
Standard 2 BHK Condominium
Standard 3 BHK Condominium
Standard 1 BHK Apartment
Standard 2 BHK Apartment
Encasing Plant
Restaurants/Cafes
Green Space/Garden
Laboratory
Theatres
Police Stations
Office Space for businesses
Water Storage
Clinic/Emergency Station
Railway Tracks
Transportation Hub

Table 1 (for each of the 6 occurrences)
Offices for Mayor
Fine dining restaurant 1
Fine dining restaurant 2
Fine dining restaurant 3
Headquarters of the F.S.
Space for Police Stations

From tables 2-6: each land use will occur thrice

Table 2
Garrison
City Council

Table 3
Control Centre
Sports Hub

Table 4
Hospital
Embassies

Table 6
Recreation
Embassies

Table 5
Malls
Business Area

Fig 4.1.1: Community Plan [Made by Viraj A in Diagrams.net]

Type	Number	Type	Number	Type	Number
Malls	5	Control Room	4	Theatres	4
Clinic	10	Control Center	3	Resorts	8
Hospital	3	Vertical Farms	4	Restaurants	40
Office for city council, staff, legal courts	15	Stem Culturing Plant	1	Garrison for US forces and Allied Space forces	1
Water Body	3	Mayor Office	1	Museums	5
Eatery (Cafe)	12	Sports Hub	3	Laboratories	5
Office Space	5	Police Stations	50	Embassies	50

Table 4.1.2: Facilities [Made by Hridank G in Canva]

4.1.2 Consumables and Consumer Goods

	Kilograms per person per year	Quantity per Year	CASSSCs per year
Shampoo, Conditioner, Soap, Skincare	1.5	71,250	4
Sanitary napkins / tampons	0.3	7,125	1
Toilet paper	0.4	19,000	1
Cleaning supplies / Detergent	0.8	34,200	2
Medications / first aid kit	0.75	32,063	2
Clothing / Footwear	4.5	203,063	13
Bedding / Linens	2	95,000	6
Paper / office supplies	1.5	60,563	4
Total	11.75	522,263	33

Table 4.1.3: Consumables and Consumer Goods [Made by Viraj A in Canva]

4.2 Resident Accomodations

4.2.1 Furniture Items

Furniture Item	Quantity	Furniture Item	Quantity
Double Bed	14000	Shower	31500
Single Bed	17500	Shower mat	38500
Coffee table	22000	Sink	38500
Dining table	22000	Side table	62000
Dining chairs	97000	Kitchen Compartment (includes sink, stove, refrigerator and cabinets)	22000
Study desk	31500	Kitchen Cupboard	31500
Office chair	31500	Cupboard	63000
Television	22000	Sofa	32000
Television Stand	22000	Patio chairs	40000
Toilet	38500	Patio table	13000
Plants	27000		

Table 4.2.1: Furniture Numbers Table [Made by Hridank G in Canva]

4.2.2 Interior Designs

Interior designs Made by Hridank G in Floorplanner

Fig 4.2.2: 1 BHK Mini Interior

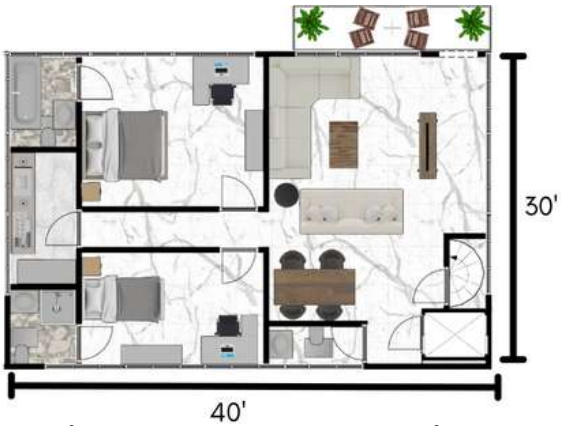


Fig 4.2.3: 1.5 BHK Interior

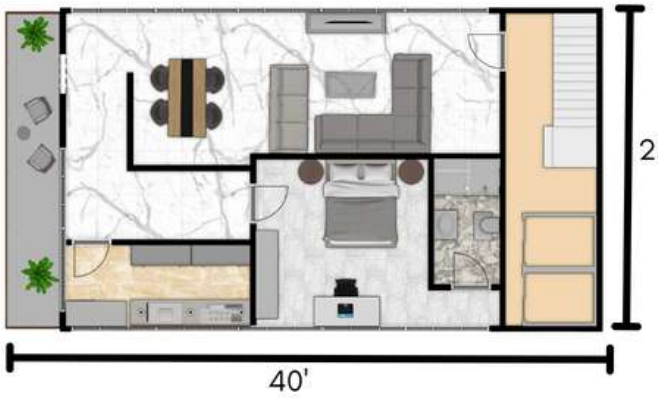


Fig 4.2.4: 1 BHK Standard Interior

Fig 4.2.5: 2 BHK Standard Interior

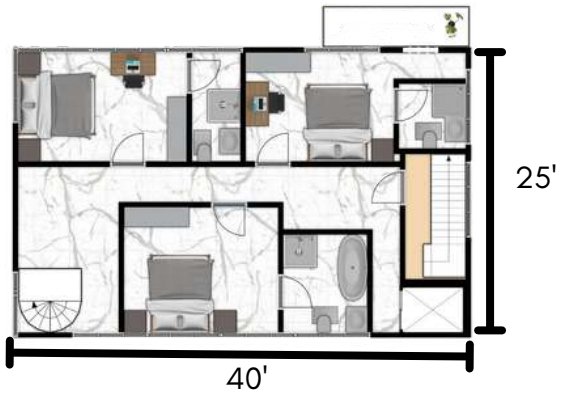


Fig 4.2.6: 3 BHK Top Floor

Fig 4.2.7: 3 BHK Bottom floor

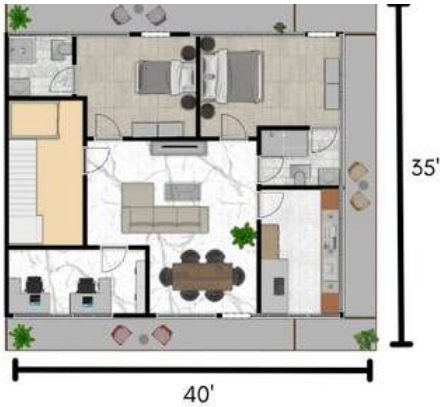


Fig 4.2.8: 2 BHK Mini Interior

Interior designs in Columbiat are those that ensure access to natural light with balconies and floor to ceiling windows.

Note that for all buildings with two flats per floor, as seen in Table 4.2.15, i.e. 1 BHK Mini and 1 BHK Standard, the flats shown in the interior will be copied on the other side of the stairwell.

4.2.3 Exterior Designs

All Exterior Designs Made by Shiv K in Blender

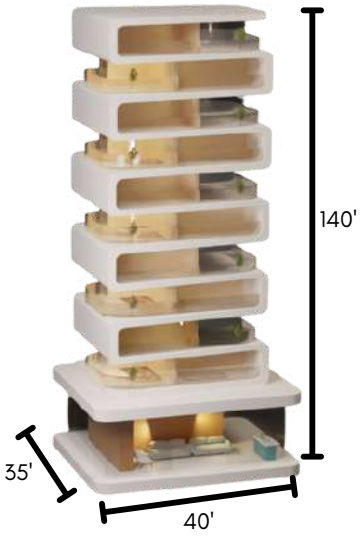


Fig 4.2.9: 2 BHK Mini Exterior

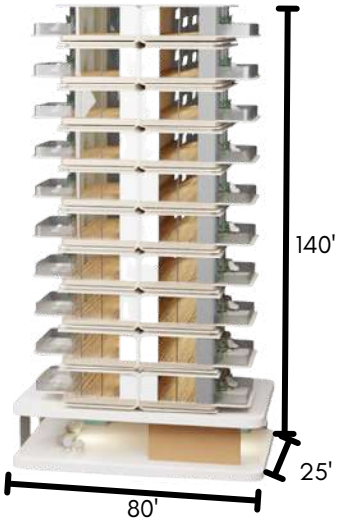


Fig 4.2.10: 1 BHK Standard Exterior

Fig 4.2.11: 2 BHK Standard Exterior

Fig 4.2.12: 1.5 BHK Mini Exterior

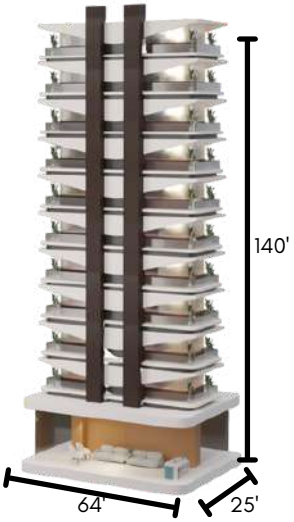


Fig 4.2.13: 1 BHK Mini Exterior

Fig 4.2.14: 3 BHK Exterior

4.2.4 Residential Table

All buildings have 10 floors

Type	Area in sq. ft	People housed	Flats per building	Number of buildings	Total number of flats
1 BHK Mini	800	1	20	550	11000
1 BHK Standard	1000	2	20	125	2500
1.5 BHK	1200	3	10	500	5000
2 BHK Mini	1400	3	10	150	1500
2 BHK Standard	1600	4	10	100	1000
3 BHK Duplex	2000	5-6	5	200	1000

Table 4.2.15: Number and areas table [Made by Hridank G in Canva]

4.3 Spacesuits and Emergencies

4.3.1 Spacesuits

Spacesuits will be subcontracted to 'Extreme Survival Technologies'.
All spacesuits will be equipped with an Artificial Intelligence Monitoring System. This monitoring system will track oxygen levels and be able to predict the time remaining for oxygen to be depleted based on a model trained on the breathing rate of that passenger. The system will also alert the passenger on when to return to the settlement based on the volume of oxygen remaining and distance from settlement.

The monitoring system will also include a communication module in order to foster communication between the control center and the passenger, especially in case of emergencies.

Each spacesuit will also have an electromagnetic tool belt equipped with a variety of tools. Spacesuits will have bright safety lights above the helmet that can be enabled by the press of a button on the right inner wrist of the spacesuit in case of the passenger being in dark areas.

Type	Specialized features	Quantity	Donning/Doffing and Stowage Area
Evacuation Situations	Contains evacuation and safety alerts	5000	Outside escape pod entries, radiation safe rooms, emergency bunkers
Manufacturing Torus	-	200	Outside entry to manufacturing torus
Outside settlement work	Thrusters for movement in space. Heat pads on fingers for comfort. Graphene Aerogel layer for insulation. Powered by solar batteries. Tethered to settlement by high strength Kevlar fiber.	400	At stations in the hub and the docks

Table 4.3.1: Spacesuit features[Made by Hridank G in Canva]

4.3.2 Emergencies

For materials that protect the settlement from radiation and solar flares, refer to section 2.1
The subcontractor Extreme Survival Technologies will be appointed for emergency and evacuation measures. Temporary off-site housing after an emergency will be subcontracted to 'Blown Away.'

Columbiat has 3 main alert features: speakers for an emergency alarm, light signals to guide visitors to their evacuation location, and screens for visual information display present. The escape pods, emergency bunkers and waterproof sealed compartments on the exterior of each building will be strategically placed throughout the habitat, distributed in a way that ensures easy access from all inhabited areas.

In the case of any emergency on the space settlement, a 4-step system is followed, as displayed on the flowchart: identify, alert, evacuate, repair.

These protocols are practiced and documented to ensure swift response during emergencies.

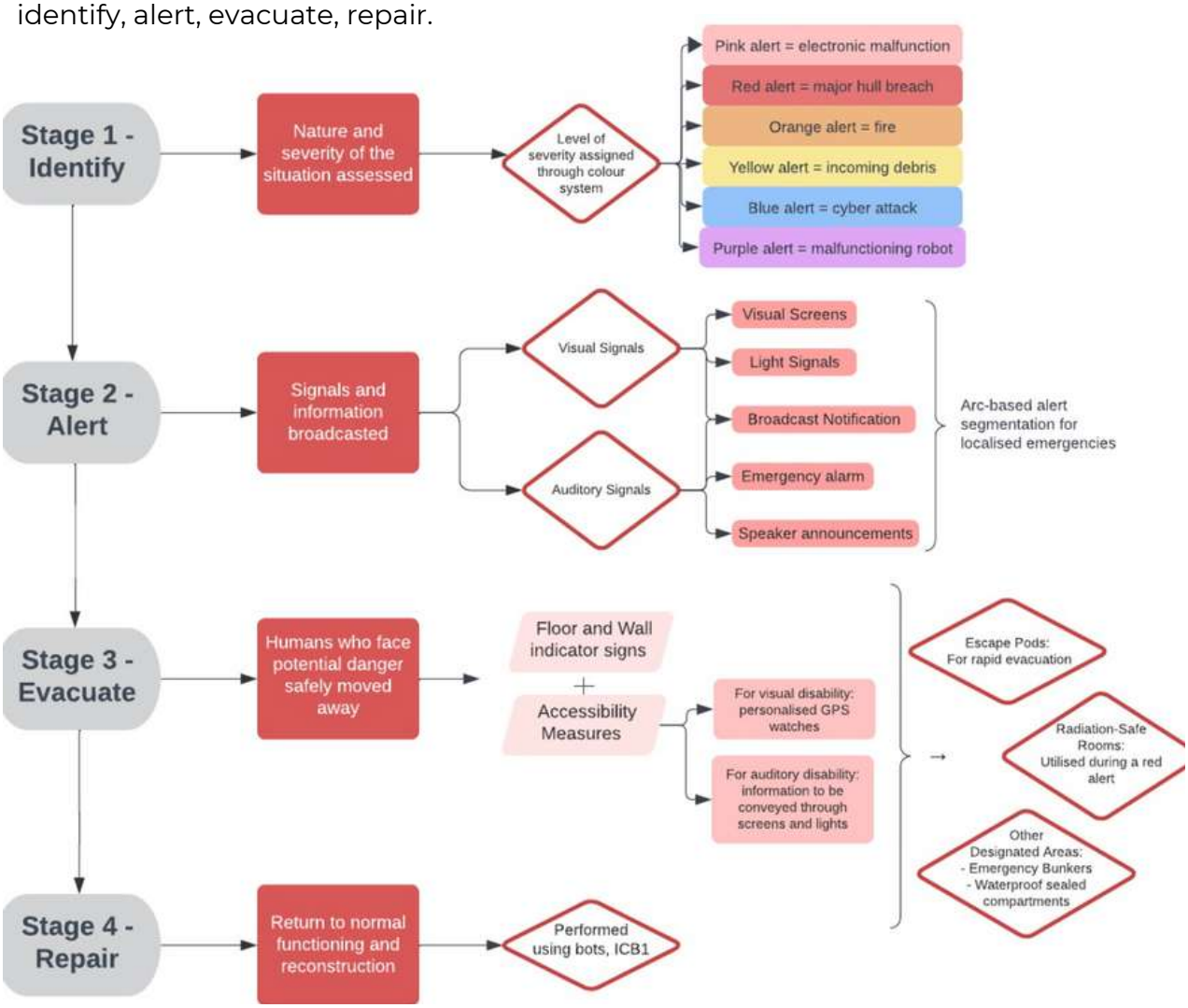


Fig 4.3.2: Evacuation Flowchart [Made by Hrishita S in Google Docs]

4.3.3 Safety for human inspection and repair

Safety systems enabling human inspection and repair of exterior surfaces of rotating volumes:

1) Fall arrest systems: These systems include harnesses and retractable lanyards, providing workers with protection against falls in high-risk areas within the rotating volumes, ensuring their safety during inspections and repairs.

2) Communication protocols: integrated communication systems in workers' helmets for distress signal communication with the control room.

3) Spacesuits: Refer to Table 4.3.1 for spacesuit adaptions for Outside Settlement work.

4.4 Public Areas in Settlement

4.4.1 Arrival/Departure Areas

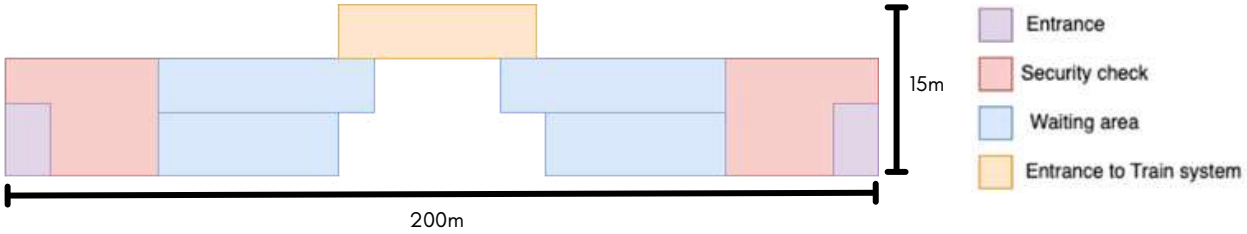


Fig 4.4.1: Arrival & Departure Floor plan [Made by Hridank G in Draw.io]

The floor-plan of the arrival/departure facilities, as seen in 4.4.1, would fit into the human transect and entrance to train system as visible in Section 3.4 (Transportation).

Note that the size of the Arrival and Departure Floor plans would be scaled based on the size of that particular human transect.

We ensure that both visitors and citizens of Columbiat will have a favourable impression upon arrival:

1. Warm ambient lighting inducts the visitors into the settlement
2. Temperature of 23 degrees Celsius provides a comfortable atmosphere
3. Television screens in waiting rooms display recreational activities and features of the settlement
4. Warm towel dispensers in waiting areas for visitors to refresh themselves

4.4.2 Security measures for visitors

Use of GPS trackers using technology in their clothes sewn together to ensure that visitors can be tracked down if need be.

Use of Radio-Frequency Identification (RFID) technology to track people's movements within the settlement to be embedded into ID cards or clothing. These tags emit a signal that can be detected by RFID readers placed at strategic locations in different control rooms and modules around the settlement. Since each visitor can be given a unique tag, a system can be enabled to monitor people.

Implement Bluetooth Low Energy (BLE) beacons within the settlement. These bluetooth devices can be attached to walls, ceilings, or objects throughout the area. People with smartphones or devices equipped with Bluetooth interact with these beacons passively.

Use of video cameras with facial recognition technology placed in public areas and roads throughout the settlement. The faces can then be compared against a database containing the facial photographs of all visitors.

4.4.3 Hotels for visitors

For visitors, columbiat offers two types of apartment-hotels. As seen in the community plan key in section 4.1, there is a 1 BHK Apartment and a 2 BHK Apartment.

Recreational facilities for the visitors and the permanent residents will be separated to foster separate recreational facilities. However, in the interest of collaboration between visitors and residents, their populations will be working together.

These apartments are located close to transport facilities, as seen in the community plan, in order to prevent too much unnecessary interference between the lives of visitors and residents.

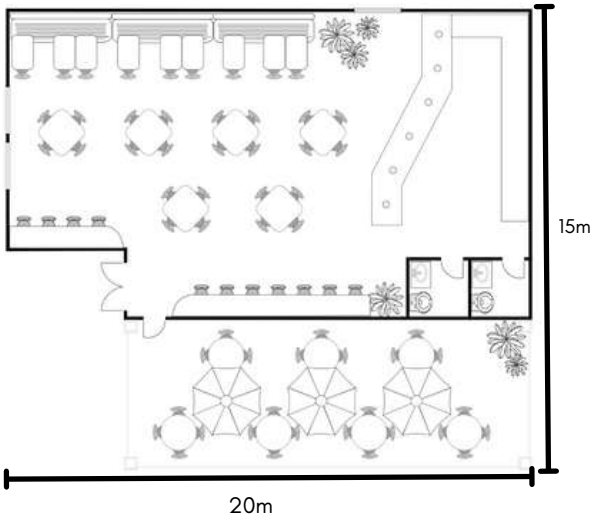


Fig 4.4.2: Restaurant in hotel [Adapted by Hridank G from SmartDraw]

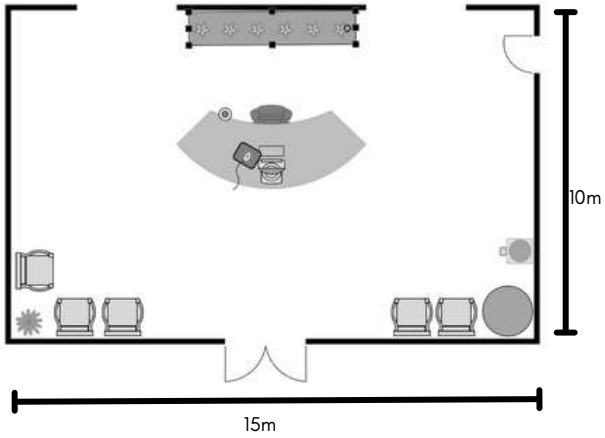


Fig 4.4.3: Hotel lobby [Adapted by Hridank G from SmartDraw]

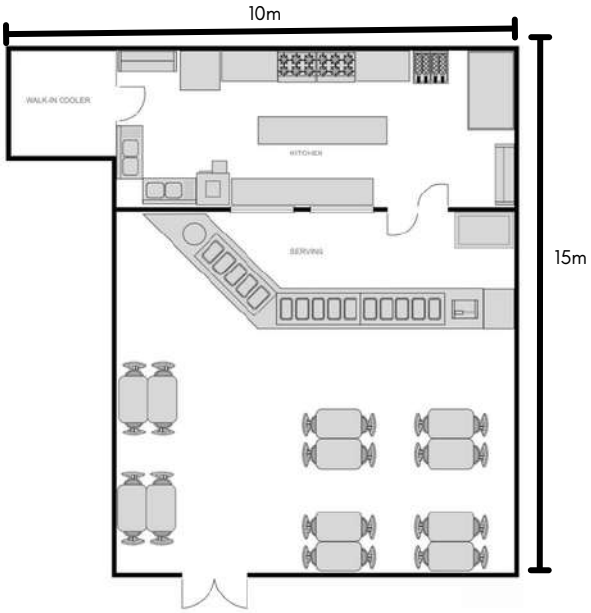


Fig 4.4.4: Shop and cafe combined in Hotels [Adapted by Hridank G from SmartDraw]

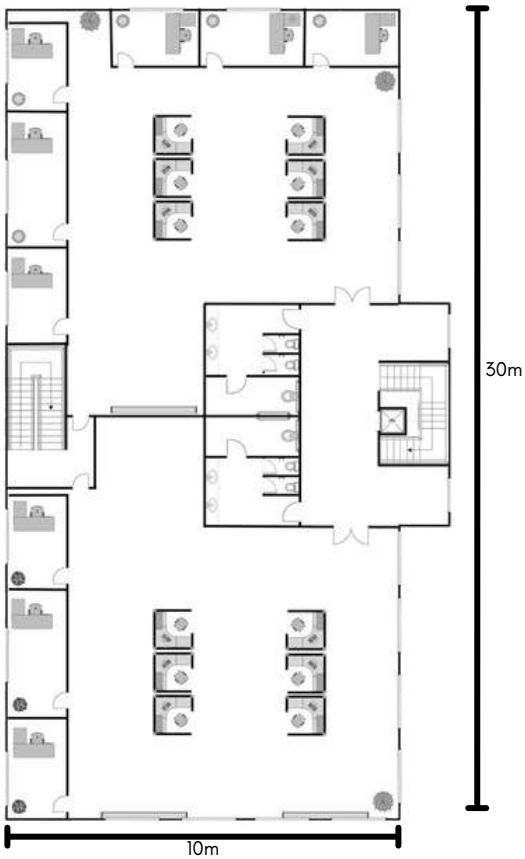


Fig 4.4.5: Hotel Business Center [Adapted by Hridank G from SmartDraw]

4.5 Distribution of People

Each arc on each structure will have the capacity of 4,250 residents: 420 of those being for transient residents, 3750 for permanent and 80 for spare capacity. With 12 total arcs, the capacity of the settlement would be 5,000 transient residents, 45,000 permanent residents, and 1000 residents spare capacity on the settlement. The 12 arcs will be divided on the 3 modules Columbiat has: A, B, and C. Inside the settlement, visitors will be distributed as per Community plans in 4.1

5.0 AUTOMATIONS ENGINEERING

5.1 Automation in Construction

Name	Features	Applications	Repurpose	Qty
Castillo	Arm, Welding torch, 3D-Printer, Storage unit for materials	An arm which can be to used to repair circuits, Furniture and Pipelines with the help of on-site 3D-Printed parts as well as welding torches to seal wireframes. 2 separate storage units 1 for 3d printing ink and the other for separate materials. This bot will also be used for placing wire systems and laying pipes down.	Weekly maintenance checks of gas and water pipelines. 3D printers can be refitted for repairs	1200
Lo	Arm, Jig, Wheels, Welding torch, Nozzle, Paint storage compartment, GPS	To build and accurately place pre-set layouts in settlements with the help of the jig; as well as use its nozzle to paint surfaces from the pre-set design sent to the bot, and coat surfaces with sealant. GPS and sensors will be used to track and map paths given to the robots.	Can be repurposed into a maintenance bot for other robots and use its paint for re-painting furniture. Jigs can be used to saw.	1250
Europa	3D-Printer, Arms, Storage unit, Thrusters, Nozzle, Welding torch, Wireless Information transmitter, Jig	Uses one pair of arms to place panels, wireframes. Additional pair of arms for 3D printing. Welding torch will be used to weld wireframes with the help of an arm. Manufacturing of hull and windows with materials in the storage compartment. To manage construction material when on site a wireless transmitter will inform the robot base to either refill or repair the robot.	External repair and damage control in cases like hull breaches.	2250
Cylene	Nano-scale storage, Nozzle, Wheels, Sensors	This bot will be used for sealing. The nanobot needs tiny sensors to find flaws in surfaces. It scans and analyzes the construction site at a molecular level. The nanobots have smart algorithms for deciding on their own. They can adjust to changes and make sealing better.	Delivery bot for minor packages.	500

Table 5.1.1 Construction Bots[Made by Taher K in Google Docs]

Image 5.1.2 Castillo
[Made by Shiv K in xyz]

5.2 Automation in MRO

5.2.1 Safety

Name	Alert	Action
Electronic Malfunction	In commercial sites and control rooms only - pink flash on ring	Switch to back-up power system. Various sensors to detect source and magnitude of error. Castillo sent for repair if human intervention unnecessary. Technicians to interfere based on feedback from Castillo and sensors like TICs, CFLS, etc
Major Hull Breach	Red alert in affected sectors and all control rooms	Evacuation of residents or workers. Lockdown of sector using air-tugs. Send Europa to fix wireframe and laydown panels. Castillo sent for sealing and assess need for possible human intervention. Intervention allowed through specialized suits. Assessment of source of breach
Minor Hull breach	Only alert in relevant control rooms	Send Lo for sealing and repair Assessment to find source of breach
Incoming Debris	Yellow Alert in all control rooms and affected sectors based on trajectory	Flares and projectile systems to destroy debris
Hacking/Cyberattack	Purple alert in control rooms	Data dumping onto redundant databases and subsequently shutting down the current network and database. Solve the issue related to the hacking. Data moved back to current servers and check for loss/stolen data. Make necessary adjustments and changes to prevent future attack.
Machine Malfunction	Alert in control room	Killswitch triggered in control rooms. Bot sent to repair center. Cause identified and rectified in other bots.
Water Leakage	control room, alarms in affected area	Broken pipes identified in control rooms and flow switched off .Repair via Castillo
Fire	Orange alert in control room, alert and alarm in area	Fire safety system Prahlad - with smoke detectors and CO alarms installed in every built-up and public areas. Gadget wiring insulated with High Temperature Epoxy Coatings for heat and flame resistance. Nitrogen based Hypoxic ORS and potassium allophanate sprinklers for large scale fires. Prahlad with sound-based extinguisher to emit low frequency waves for small scale fire. All suppression and detection systems are nodes in Prahlad and operate based on detected temperature change, smoke content. Easy to use oxygen masks to be supplied and maintained throughout the settlement

Table 5.2.1 Contingency Plans[Made by Mokksh S in Google Docs]

5.2.1.2 Accessing Critical Data

Only those who are supposed to have access to these systems must have access in order for the technology to operate properly and for the data to be kept private and secure for the benefit of the passengers. Therefore, depending on their sensitivity, several levels of safety are used to encode critical data.

All automation systems are completely under the control of people. All automation systems have killswitches, which restrict access to authorized persons exclusively. Human assistance is sometimes used by automated systems for certain circumstances and tasks. Repairing electricity lines, bots, pipelines, machinery, finding lost items, and other tasks are typically managed by automation systems, but occasionally, a human may need to step in.

5.2.1.3 Collaboration with humans

Automation System	Function
WizardOS	Predicts malfunctions and unforeseen events, such as solar flares, approaching space debris, and small stones, and uses AI with knowledge of similar issues in the past as well as circumstances of the present to suggest necessary action. Additionally, it anticipates power surges based on the time of day and the number of users, and while informing the control center, shuts non-essential services in accordance.

Table 5.2.2 Automation System[Made by Mokksh S in Google Docs]

Type of data	Level of security
Personal Information, user files, drives	Fingerprint and/or alphanumeric key
Necessities' levels monitoring	Fingerprint + alphanumeric key
Settlement information, blueprints	Iris scan
Bot Allocation	Iris scan + alphanumeric key
Killswitch	Iris scan + Fingerprint + Alphanumeric key

Table 5.2.2 Accessing Critical Data[Made by Mokksh S in Google Docs]

5.2.2 Repair

In the same space as external ship repair near the docks, will be the area for bot systems, machine repair. To avoid extra repair machinery and overstocked parts, the same machinery can be used for all machines unless required. Separate sections within the facility for different bots shall be allocated with relevant parts available where they will undergo scheduled maintenance as well.

5.2.3 Maintenance

At regular intervals throughout the town, electrostatic sprayers and foggers are positioned to opportunely disinfect the air and surfaces. Cleaning and painting tasks are transferred to minor construction bots. There will be pressure sensors at different identified key areas of the external structure that are subject to extensive movement or are crucial to settlement integrity which periodically report structure health to the control rooms and help decide whether maintenance is required.

5.3 Automation in Liveability

Liveability

A digital ring system will serve as each resident's personal assistance device. It will be a node in the communications system, allowing for instantaneous browsing, file-transfer, calling and messaging. Equipped with a mini-AR and holographic projector, it will also serve as each user's individual access key. The GUI can also be projected onto other larger screens linked to the network in the settlement to serve as entertainment providers. Biosensors for posture, heart-beat, sugar-level, etc will feed information into a central Liveability AI system, which may generate personalized recommendations, warnings to healthcare providers during emergencies or information regarding best productivity practices to workplaces. The ring will provide information to access

Fig 5.3.1: Digital ring [Made by Taher K in Gencraft]

Manual Labour

Cleaning bots will be subcontracted to Bots4U. Drink dispensaries to be present in every residential area and workplace. Cooking bots can prepare food on command or through the Annapurna feature of Frigg, which also monitors nutrient composition, caloric intake and can make suggestions or warnings via the ring.

Name	Function	Qty/ Data Capacity
Frigg	Home customization system, modular furniture modifier, wall color. Has the same functionality in workplaces.	1 per home/8EB
Nord	Block-chain based digital finance gateway, can be linked with projecting system to provide financial information	1 per user/ 4 TB
Eliza	Workplace AI system, allows for file organization, analysis, translation and transcription through personal device linkage	1 per user/ 4 TB
Lumiere	Infotainment system for Metaverse connection, VR access and advanced features not in Canary	1 per user / 2 TB

Table 5.3.1: Livability [Made by Taher Kachwala in Google Docs]

Residences

FriggLiveability network manages each home, connecting personal devices and bots via iris biometrics. CareCanaries, individual assistance bots, provide info, fetch items, and manage household tasks. They coordinate with Frigg for robot and system tasks. Users can request maintenance, cleaning, or food/drink via verbal or GUI commands. Canaries also perform safety scans and offer entertainment. They facilitate appointments, communication, and customization.

Homes, uniform in size, feature modular design, movable walls, and projected wallpaper for personalization.

Workplace Productivity

Cleaning bots will be subcontracted to Bots4U. Drink dispensaries to be present in every residential area and workplace. Cooking bots can prepare food on command or through the Annapurna feature of Frigg, which also monitors nutrient composition, caloric intake and can make suggestions or warnings via the ring.

Name	Function	Qty	Dimensions
Andromeda	Medical robot that aids surgeons in their work	3 per medical facility	5*5*2
Sombrero	Medical robot that aids surgeons in their work	50 Settlement-wide	2*2*2
Pinwheel	Security robot to defuse human conflict and provide a perimeter of protection around dangerous regions	150 Settlement-wide	3*3*3
Cartwheel	Knowledge-base bot that educates inhabitants	30 Settlement-wide	1*2*1

Table 5.3.2 : Public support [Taher K in Google Docs]

5.4 Automation in cargo management

Warehousing:

Modular and expandable warehouses within the settlement.
Designed for temporary storage of various goods and bulk materials.
Climate-controlled compartments for sensitive cargo.

Inventory Management System:

Itemised inventory with quantities and locations.
Real-time status updates.
Alerts for low stock levels.

Process:

Utilizing AI, cargo movements are meticulously tracked, recording historical data including location, type, and time. Spacecraft efficiently unloads CASSSCs via vacuum astro bridge onto a conveyor belt, hence securing them for smooth movement.

RF-ID technology scans CASSSCs and packages, directing them to assigned locations based on contents and handling requirements. Robotic systems manage CASSSCs, sorting similar items, optimizing storage, and ensuring efficient access. Containers are tagged with unique identifiers for precise tracking. AI efficiently allocates storage, considering size, access frequency, and delivery priority. Internal transport systems move packages to designated storage areas. Upon arrival, packages are scanned, data transmitted to a control panel, and cloud server for real-time tracking. When discharged, departure time is recorded in the cloud for continuous traceability, enhancing inventory management.

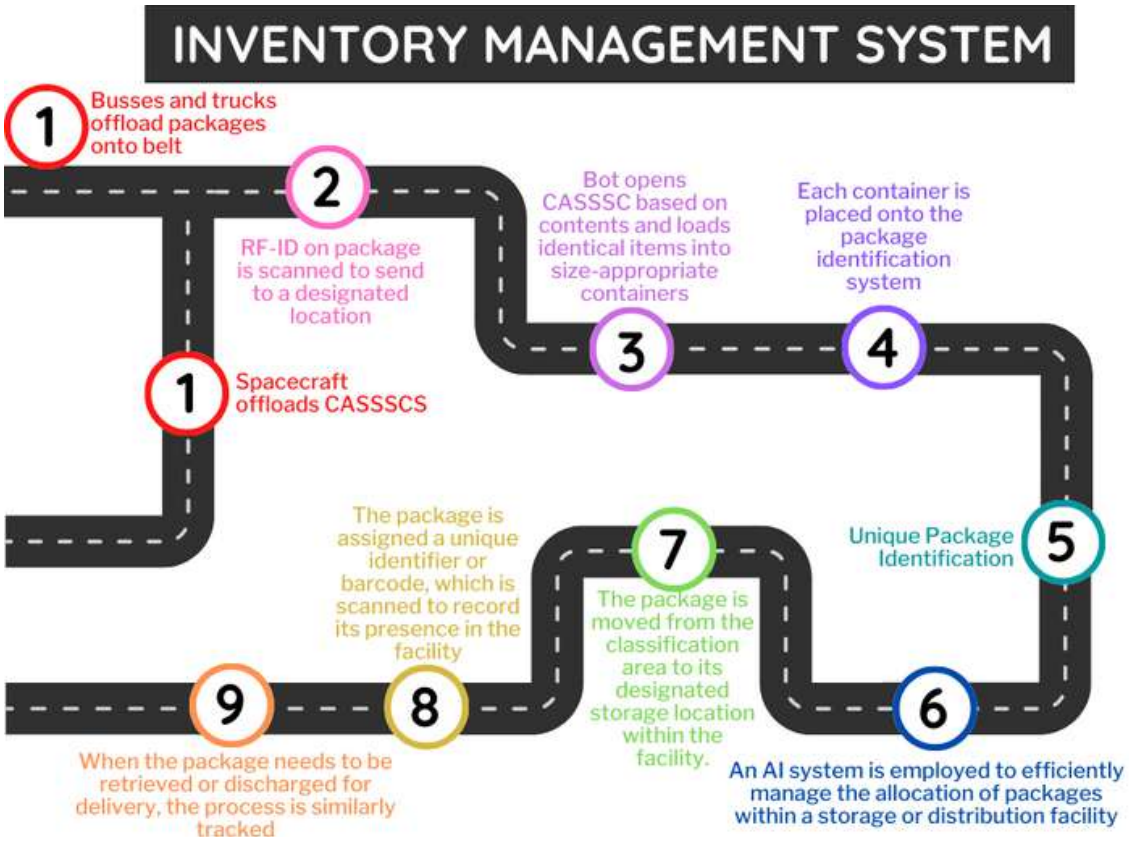


Fig 5.4.1: Inventory management system flow chart [Taher K, Canva]

Fig 5.4.2: Astro belt [Made by Taher K in Gencraft]

Fig 5.4.3: Conveyer belt [Made by Taher K in Gencraft]

5.5 Communications

Computing centers, based on hybrid and multi-cloud storage principles for efficiency and utilizing solid-state drives, will be distributed throughout the settlement with a focus on industrial zones, critical administration centers and infrastructure sites. A modular system of network development will be adopted to inculcate latest developments in data transfer and mass-storage as private data-demand increases with commercialisation. Cloud computing instances will be autonomously provisioned, scaled, and decommissioned based on real demand, to improve resource allocation for cost-efficiency. Instances must be developed in a modular fashion to allow improvements over time.
The AI based GanymedeSystem will facilitate data-management, access, transfer and creation protocols based on individual company preferences, with internal communication facilitated by the Rowley antifragile quantum architecture, as mentioned in 3.2.
The GanymedeSystem is to have the following capabilities for security and communication needs -

Encryption Management - encryption protocols for internal communications will be managed, optimized and self-corrected using a personalized user interface for each company. The CipherPro Quantum Key Distribution(QKD) system will generate encryption keys using a random generation system for communication between different nodes in internal systems, with relevant access keys and manuals encoded in the Ring personal device. Different subunits or companies can use the Rowley architecture's QKD generator to create specific channels for external communication, leading to safe, instantaneous communications.

Inter and intra-company communications facilitating discussions, transactions or information sharing will be facilitated through Rowley's quantum entanglement protocol. Here, a specific number of multilateral communication codes or "quantum keys' ' can be created and shared by communicating parties and transferred v-a the system of quantum repeaters and fiber optic cables present throughout the settlement. Information can be encrypted and attached using the quantum gate allocation on Rowley's UI, with the correlated nature of shared keys allowing for instantaneous data transfer, with no potential of third-party malpractice.

The usage of quantum communication will ensure streamlined workflows for approvals, resource allocation requests, and compliance checks, quickening internal and external decision-making processes.

Intelligent Data Routing: Quantum routing systems switches autonomously manage data routing, optimizing the fastest and most secure pathways for intercompany data transfer, based on nature of data transfer, industrial preferences and self-customisation through the CipherPro platform.

Based on the selected keys, different security, time-priority and information size levels can be agreed upon between vendors for transactions or by different units in companies to maintain discretion.

Decision support system of Ganymede - AdaHop - to provide real-time recommendations for resource allocation, cybersecurity responses, and infrastructure management to relevant personnel based on company settings and protocol

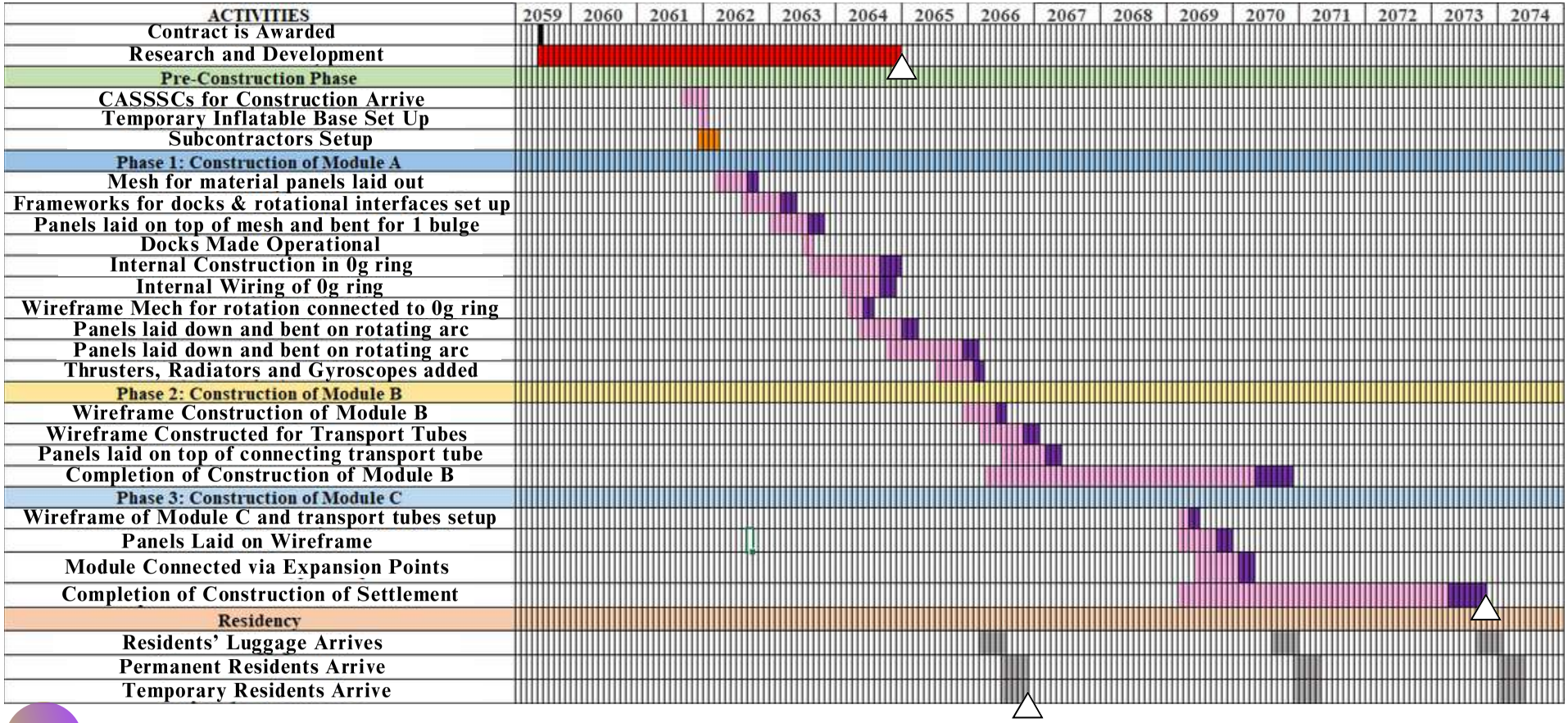


Fig 6.1.1: Schedule for Columbiat [Made by Viraj A in MS Excel]

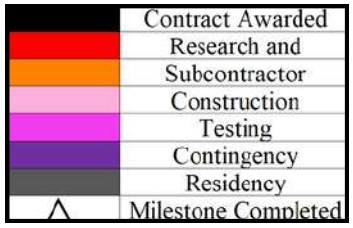


Table 6.1.2: Key for Schedule [Made by Viraj A. in MS Excel]

6.0 SCHEDULE AND COST

COSTING

Materials Cost (Some materials will be subcontracted as indicated in Section 2.1 and 3.1)

Material	Volume	Mass	Total Cost
Aluminium	2550100	6885270000	48,196,890,000
Lunar Regolith	3809700	5714550000	3,143,002,500,000
Aluminium MMC	125000	356250000	2,137,500,000
AM-III Carbon	12400	28024000	1,289,104,000
Aluminium Oxynitride	61700	231375000	27,765,000,000
Silica Aerogel	668000	106880	3,206,400,000
Polyethylene	25000	24250000	48,500,000
		TOTAL	3,226,697,466,400

Fig 6.2.1: Materials Cost[Made by Viraj A in MS Excel]

Robot and Software Cost

Item	Unit Cost	Quantity	Total Cost
Castillo	350000	1200	420,000,000
Lo	750000	1250	937,500,000
Europa	500000	2250	1,125,000,000
Cylene	200000	500	100,000,000
WizardOS	2000000	1	2,000,000
Digital Ring system	12000	50000	600,000,000
Frigg	45000	22000	990,000,000
Nord	30009	22000	660,198,000
Eliza	12000	22000	264,000,000
Lumiere	34000	22000	748,000,000
Andromeda	100000	34	3,400,000
Sombrero	125000	50	6,250,000
Pinwheel	100000	150	15,000,000
Cartwheel	100000	30	3,000,000
		TOTAL	5,874,348,000

Fig 6.2.2: Robot and Software Cost[Made by Viraj A in MS Excel]

Buildings Cost (in million

Item	Area per floor	Number of floors	Total cost
Malls	1200	5	358,350,000
Clinic	225	1	22,500,000
Hospital	2500	5	597,937,500
Sports Hub	9000	2	915,030,000
Eatery	625	5	391,687,500
Office Space	1200	5	120,000,000
Laboratories	600	5	180,000,000
Offices for Government	13950	7	4,000,000
Police stations	100	2	5,081,250,000
Embassies	1200	3	69,450,000
Garrisons	10000	3	1,350,000,000
Resorts	11148.36409	10	360,000,000
Restaurants	1858.060681	10	17,342,395,178
theatres	2787.091022	10	7,762,977,525
Mini 1 BHK Condominium	74.3	10	1,337,803,691
Standard 1 BHK Condominium	92.9	10	4,472,674,250
Standard 1.5 BHK Condominium	111.5	10	1,270,988,125
Mini 2 BHK Condominium	130.1	10	6,101,837,500
Standard 2 BHK Condominium	148.6	10	2,135,916,750
Standard 3 BHK Condominium	185.8	5	1,626,427,000
Standard 1 BHK Apartment	74.32242724	10	1,016,790,500
Standard 2 BHK Apartment	92.90303405	10	1,220,188,449
		TOTAL	1,016,823,708

Fig 6.2.3: Human Factors Cost [Made by Viraj A in MS Excel]

Operations Cost

Item	Cost Incurred
Atmosphere	6,000,000,000
Electricity	4,500,000,000
Communications	6,450,000,000
Food	5,100,150,000
Water	150,000,000
Transport	3,000,000,000
Total	25,200,150,000

Fig 6.2.4: Operations Cost [Made by Viraj A in MS Excel]

Total Cost of the Settlement

Area	Cost
Materials	3,229,903,866,400
Operations	25,200,150,000
Human Factors	54,755,027,676
Robot and Software	587,434,800,000
Total	**3315,733,392,076**

Fig 6.2.5: Total Cost [Made by Viraj A in MS Excel]

7.0 BUSINESS DEVELOPMENT

7.1 Transportation Node and Port Serving Companies

Cargo

There are 5 docks available on each of the six 0-g bulges. Cargo (CASSSCS) from spacecraft will be offloaded via a cylindrical vacuum system onto a conveyor belt for loading onto the cargo dock. RFID tags will scan and categorize cargo, guiding the allocation of storage spaces through an AI system that optimizes efficiency. Each container will be tagged for tracking and historical data storage. Real-time monitoring via a central control panel and cloud server will ensure visibility and accountability. This system streamlines inventory management and traceability within the facility. Once packages are assigned storage locations, an internal transportation system, which can include conveyor belts, robots, or other efficient mechanisms, will take control. The warehouses will be climate-controlled compartments accommodating all kinds of cargo. For more information refer to Section 5.4.

Passenger Traffic

As illustrated in Section 4.4.1, there is an area for the visitors of Columbiat to enter and then undergo a security check. The waiting areas depicted on the floorplan in Fig. 4.4.1 will have ample space to allow for residents entering from different parts to wait while other populations are catered to. The docks, in this way, will be able to cater to a wide range of populations such that different people can visit it at different times.

The train system, as seen in section 3.4, will transport inhabitants from the docks to the hotel facilities at a rapid speed such that the capacity in the docks remains low and not crowded. In this way, residents can quickly make their way to the hotels such that they can stay there. The central control room present will allow and facilitate the use of space in the docks, such that space is efficiently allocated. This central control room would be able to assess and appropriately calculate the number of residents required in any particular area.

Refueling, Repair and Docking

On the docks, there are different repair services present to cater to each of the different functions, including refueling, repair services, and tugs. Support will always be available on the docks by a staff of engineers present in quarters on the docks. These designated quarters on the docks will contain equipment that would aid in the maintenance and upkeep of any spaceships that need to be repaired. In case of any emergency on the docks, these quarters will also be equipped with spacesuits fit for exterior work, such that the workers are prepared to exit the craft accordingly. Also, there would be fuel stored safely for the ships that are being towed in this area.

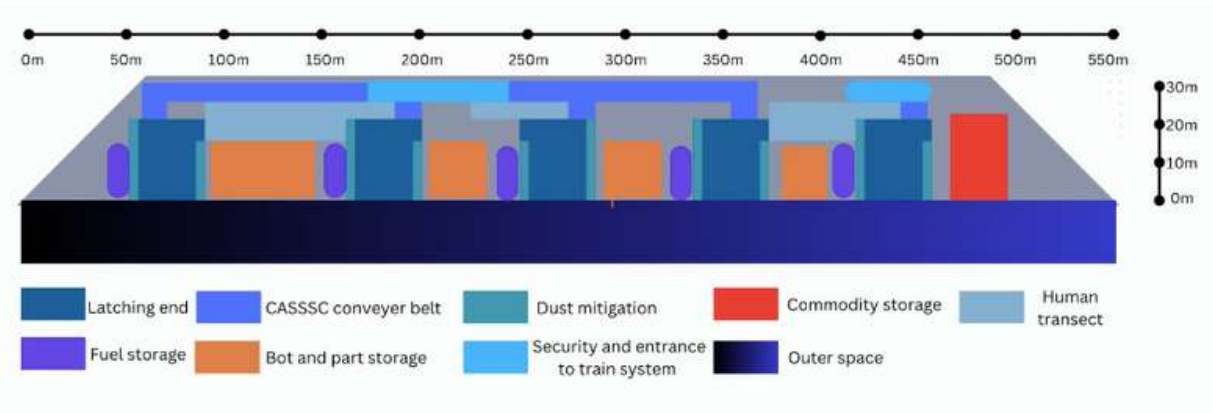


Fig 7.1: Floor plan for Docks [Made by Kcavyan A. on Canva]

7.2 Commerce, Financial, and Tourism Center

Office Facilities

A primarily commercial and business settlement in space, it is essential for high-technology and well-equipped office facilities. Covering a total area of approximately 209000 m2, office facilities will consist of several features to increase accessibility and maximise the efficiency of business to cater to a diverse range of businesses, including space technology companies, financial institutions, law firms, and research organisations. The interior design prioritises functionality, providing modern workspaces equipped with state-of-the-art communication and collaboration tools (such as interactive whiteboards, smart projectors, video conferencing systems), ergonomic furniture, and sustainable energy solutions. Meeting rooms, conference facilities, and co-working spaces are readily available to encourage collaboration and innovation among resident businesses. Advanced security measures, including biometric access control and 24/7 surveillance, will ensure the safety and confidentiality of sensitive information.

Stock Exchange

The stock exchange facility will be a technologically advanced trading area that operates both physically and electronically, a prime business hub on Columbiat, covering an area of 1400 m2. It features a digital trading platform with real-time data feeds, enabling traders to buy and sell space-related stocks, bonds, and other financial instruments. The stock exchange will also host regular seminars, workshops, and educational programs to educate residents about investment opportunities.

Financial Services

Key aspects in any financial transaction: banking, investment, and lending/credit services will play a large role in the settlement. In addition to these services, Columbiat will embrace cutting-edge fintech solutions, such as blockchain-based smart contracts for space-based transactions and digital wallets for frictionless interstellar commerce.

Foundation Society HQ

The Foundation Society Headquarters serves as the central administrative and operational hub for the organisation. It features a combination of office spaces, meeting rooms, and event facilities to facilitate the Foundation Society's initiatives. The headquarters houses a team of dedicated professionals who manage various projects aimed at enhancing the quality of life for Columbiat residents.

Business Hotels

These hotels offer modular room designs, allowing for flexible layouts to meet the specific needs of guests. They include conference rooms equipped with holographic teleconferencing technology for business meetings. Each room is soundproofed to ensure a quiet and comfortable stay.

Activities

Recreational spaces, especially within a business centric settlement, are an essential facet of human life, ameliorating one's physical and mental well-being. Placed throughout the settlement, the following recreational ideas are easily accessible to all residents.

Key for Activities

Symbol	Meaning
	Activity performed individually.
	Activity performed in groups.
	Intellectually stimulating activity.
	Activity requiring physical exercise.

Zero-g Recreation

Activity	Description
Gardening areas	These areas would also serve as research facilities for zero gravity plant growth, and allow residents to connect with nature while working towards scientific advancements. AI-driven systems monitor and optimise the growth conditions for plants in the gardening area. Sensors collect data on humidity, temperature, nutrient levels, and light, and AI algorithms use this data to create ideal growth conditions for various plant species.
Planetary Archery	A twist on classic earth archery, targets would have different magnetic fields around them, which means that players will need to be creative in order to shoot a target.
Exoplanet Hiking	This immersive virtual reality adventure offers guided hikes on meticulously designed simulated exoplanets. Participants don VR headsets to explore stunning landscapes, learn about the unique characteristics of each exoplanet, and engage in both recreational and educational experiences.
Dodge Ball	High-energy 3-D dodgeball matches where players dodge floating objects while competing in a zero-gravity arena.

Gravity Recreation

Activity	Description
Theatres	The theaters are constructed with acoustically designed walls and ceilings to ensure optimal sound quality during performances. They feature adjustable seating arrangements to accommodate various audience sizes. Cutting-edge holographic projection technology allows for immersive 3D presentations.
Observatories	The observatories are located in shielded areas of the settlement to reduce interference from artificial light. They feature retractable domes with advanced, self-cleaning glass. Telescopes are mounted on computer-controlled tracking systems to precisely focus on celestial objects.
Sports centre	The sports center has multi-functional courts that can adapt to various sports, such as basketball, volleyball, and badminton - and even a climbing wall with safety harnesses and auto-belay systems. The gymnasium is equipped with exercise machines designed for low-gravity use, and a running track encircles the facility. Specialized air filtration systems maintain air quality for physical activities. A yoga, dance and aerial silk studio would also be present for wellness.
Shopping mall	The shopping areas are designed with modular storefronts that can be easily reconfigured to accommodate different types of shops and market stalls. An automated inventory management system ensures that goods are readily available. Within the shopping mall, residents can access AI-driven personal shopping assistants through their wearable devices or mobile apps.

Table 7.2.1-7.2.3: Recreation Activites and Key [Made by Hrishita S.]

7.3 Governance, Legal, and Defense Services

Offices for mayor, city council, and staff

Due to the small population of 45,000 people, there will be one “City Hall” for both the mayor and the city council. The departments will include public works, health, construction, recreation, and zoning regulations. The City hall would comprise of the Mayor’s Office, City Council Chambers where public service meetings would be conducted, and the clerk’s office. The city council, additionally, would be developing common infrastructure, permitting buildings and recording property registrations. Through tax collection, the government can earn revenue. Such features of a government can be applied to different other settlements, which would also earn profit to the city council.

Police

There would be around 175 policemen on-board the settlement located at different areas across the settlement in small police stations. These stations would be equipped as necessary to handle cases of non-compliant citizens to the law as set by the city council and judiciary members. Tax revenue would fund the operations of the policemen and the maintenance of their stations dispersed around the settlement. There are 24 police offices located across the settlement, 8 in each of the 3 modules. As a business, it must operate on a budget which would be set by the public works office and maintained accordingly.

Embassies of Terrestrial Governments

There would be embassies used to communicate with the home country. This home country can be involved in the case of any emergencies onboard, including sudden medical emergencies or the demise of any members of the settlement. The embassy would also be responsible for monitoring the tax payments and filing for all the people on board. The embassy would be responsible for understanding and enforcing the relevant system for filing taxes for the populations of different nationalities. Each embassy would be allocated an office in a way to represent the proportion of the residential population with that nationality.

Legal courts

The legal system will comprise of 2 district courts, a circuit or county court and an appellate court which acts similarly to a supreme court. Specialised courts won’t be necessary, they would be addressed by either a district or circuit court depending on the case type. The district court would handle minor cases such as traffic violations, misdemeanours, and civil lawsuits. Preliminary trials by the district court will dictate if a case will proceed to the appellate court or not. The one circuit court will act as an intermediate-level trial court. The appellate court will handle the most complex cases ranging from administrative, civil and criminal appeals, to interpreting statutes. They may conduct reviews of the lower courts’ decisions. Maintenance of appropriate property records would be achieved through an online digital database accessible by the legal courts. The records would include deeds, mortgages and leases. Data related to properties assessed for taxes will also be recorded and stored in the database. Records such as deeds and titles will be held at the county and municipal levels. Such databases would contain information about the different space allocations present onboard. Refer to the HF 4.1 for the floorplan and the allocation of space within the floorplan.

Garrison

Following a soldier to civilian ratio of 1:100, the Columbiat will have 500 troops stationed at a garrison covering an area of approximately 3km2.

It will be strategically located within the residential arcs with easy prioritised transport access. The garrison doubles as a training base as well. The facilities will include 10 barracks along with accommodations for around 50 personnel members (support, medical and training staff). A command and control (C2) centre would be in charge of analysing data, communication, training, and emergency response drills. Logistics and supply depots would handle resource management along with storage and warehousing. Security infrastructure including perimeter fencing and surveillance control and medical facilities would also be accommodated.

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Table 8: Appendix C: Compliance Matrix [Made by Viraj A.]