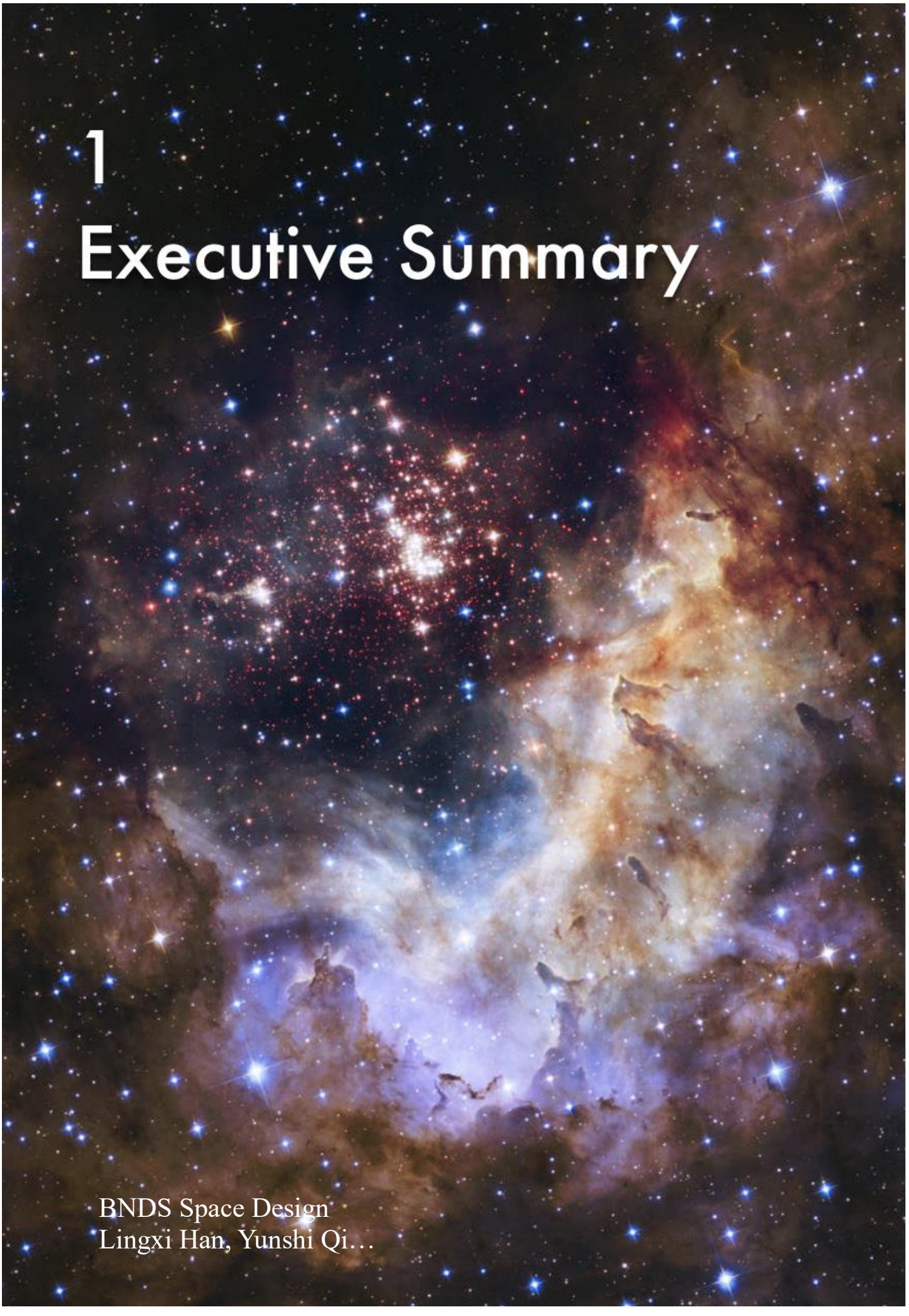


1 Executive Summary

BNDS Space Design
Lingxi Han, Yunshi Qi…

1.0 Executive Outline

Design Concept：people-oriented, time efficiency to benefit people, and environmental benefits to benefit sustainable development

People-oriented, time efficiency to benefit people, and environmental benefits to benefit sustainable development. Through using the well-priced materials with convenient and advanced technology, our company' design concept aims to both create a healthy and convenient place for our residents. We designed Also, using robots with artificial technology, for example, we have designed dust cleaner robots and wearing assistant machine in order to help our residents save the time of sanitation process and managing our appearance. We also designed aerobic exercise area for biking and running, climbing area, and public rest area that provide residents full opportunities of doing exercises and keep their body's fitness.

These area will provide different feeling to the residents.

Our company is people-oriented, and always think from our customer' perspective. Thus, we will always try our best to provide our sincere service, and improve ourselves with the needs of our customers step by step.

The mind of absorb the quintessence and look forward the future

Our company will build an industrial space settlement in space that would sustain for long period of work.

Our design is dedicating at making LX-2 as an advanced development of human space tourism, which is not only for its popularity but also for its development industry of space tourism.

In the future, the development of humanity and technology is no longer limited on Earth, but the wider place—space. As a matter of fact, we will develop LX-2 asteroid mining business and set up it into the most important connection between human and space. This is not for commercial benefits only, but for the common development and break through of humanity.

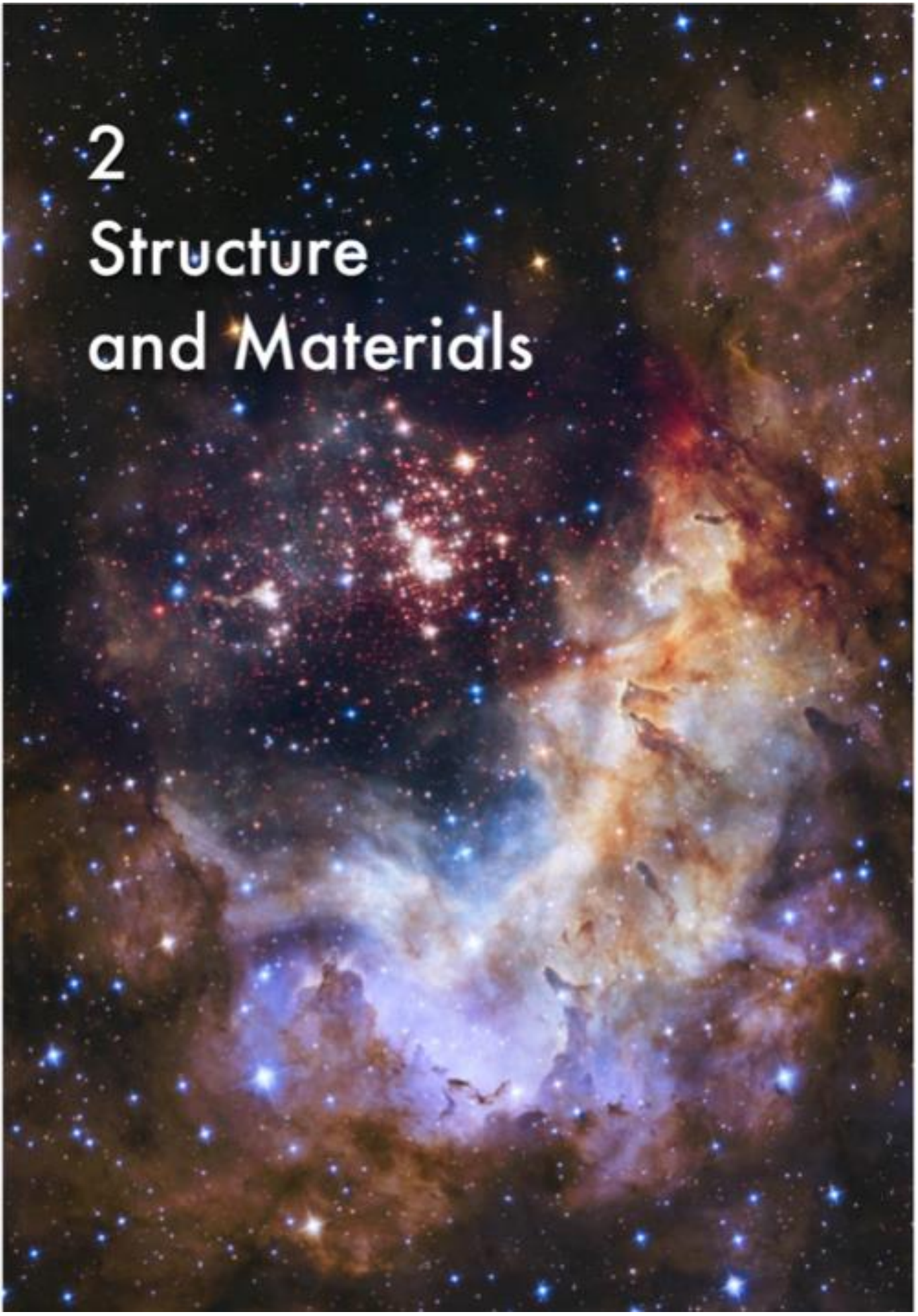
Conduct technology development, construct advances.

Mature technology with full of experience and innovation minds are marvelous advantages for our company to build LX-2. Our company has more than a thousand high-tech staff from different schools and research institutions. Our company will always have contact with those people in order to explore new aspects of science and technology.

Also advanced technology was brought up by advanced systems. Our companies gathered solar power generation, gas power generation, cycle system, and asteroid mining and other technologies to solve the needs of operation and residential systems like water, air, electricity, and so on. Also our company has developed a number of space industries which provides considerable income and huge follow-up impact for the space city.

Distinctive environmental friendly aspect for environment and the value of the world

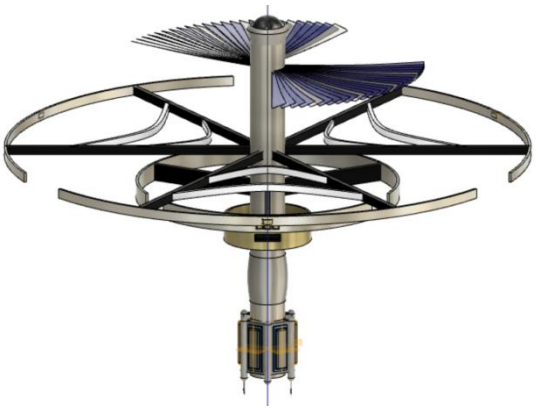
Our company is willing to implement and achieve the combination of machine and nature by using human's marvelous success in the field of technology. Automation machines we used have covers such variety of different area that provide most convenient and comfortable community for our residents. Dedicating to protect the environment of shuttle and the space so that we can maintain this development for longer years.The fuels we used for providing electricity or other sorts or energy, are totally composed by recyclable and clean resources that would not bring any contamination of leakage. Our company first starts from energy sources that might produce potential risks to environment in order to achieve "close to nature". We consider the quality environment would be the most essential part if we want to close to nature. As our company is one of the millions of the companies which have same targets or dreams, we think our value to the world is to provide our own unique considerations towards each part of the space shuttle. Space, the final frontier. The voyages of human would never be stopped, to bravely go where no man has ever achieved. Our company believe that we would continue to create the value of our own to the world, to humanity, and never stop our enterprise.

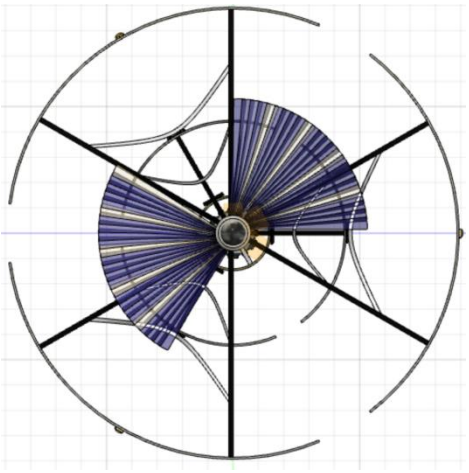


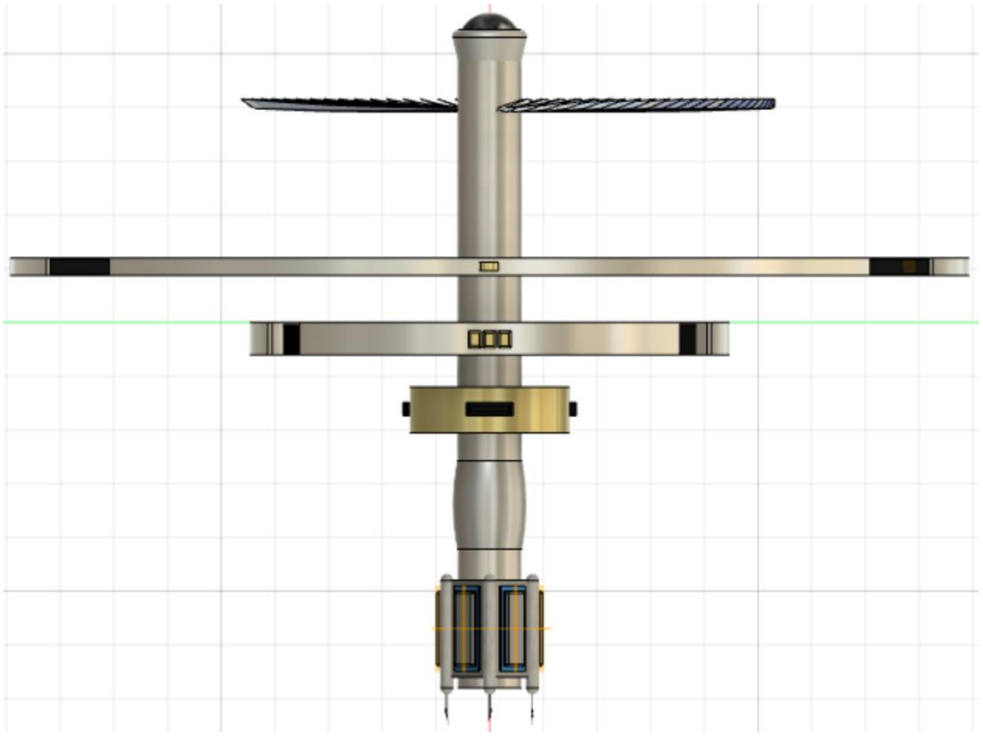
2 Structure and Materials

2.1 Overall Design

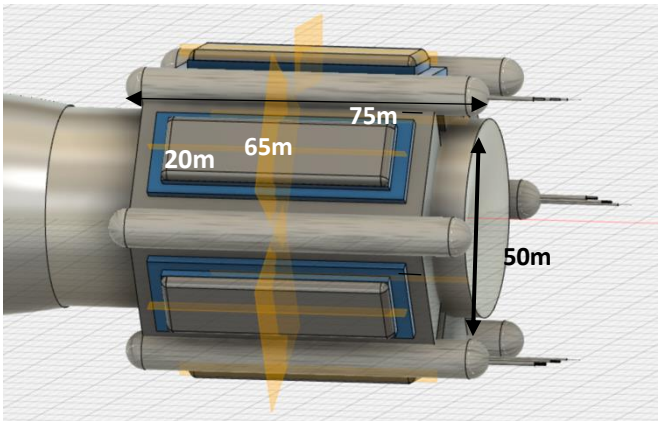
According to the requirements, the Vulcan space station we designed is mainly divided into the following parts: port, central axis for transmission, solar panel, residential space, Industrial space and agricultural space.





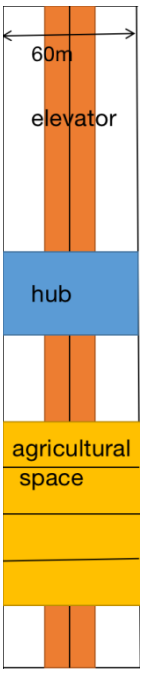


2.1.1 Port



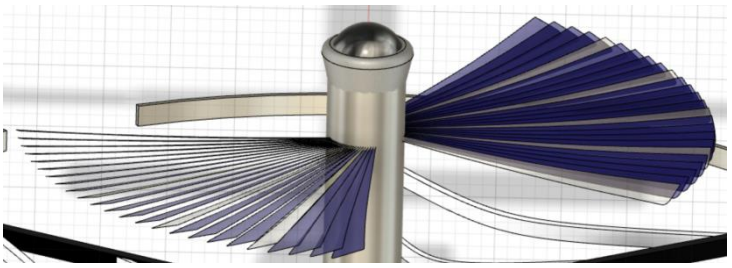
Our port has 6 docking ports of 20m x 65m to dock the spacecraft with the space station. Three of the six 75m long cylinders on either side of the port will house the antennas, while the other three will serve as temporary storage.

2.1.2 Central Axis



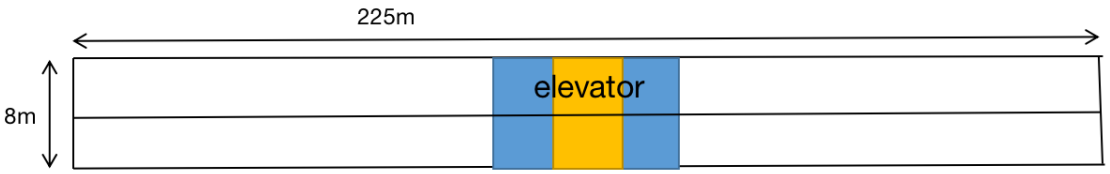
There are six elevators on the central axis, two for residents and four for freight. Residents usually do not come to the central axis, so there are fewer elevators.The central axis also includes a hub to other ring-like areas such as residential Space, and 0g agricultural space and industrial space.

2.1.3 Solar Panel



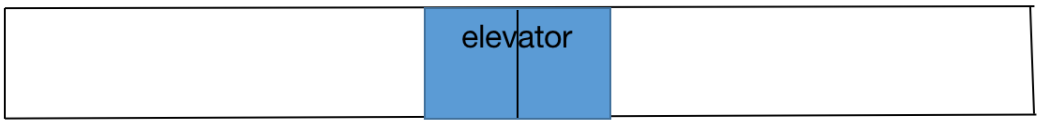
We designed the solar panels in the shape of fans. In the event of a danger (such as a meteorite), the solar panels fold up like fans into sticks, reducing the chance of being hit.

2.1.4 Residential Space



Residential space is divided into two floors with elevators that can shuttle between floors or reach the hub. In fact, residents or tourists do not need to leave residential space at all, because residential space has a large area and can meet all the requirements of people's life. And without residential space, gravity is no longer the 0.5g that people adapt to.

2.1.5 Industrial Space



The Industrial space is divided into three parts: 0g, 1/6g and 1g. Located on the central axis, the largest ring and the smallest ring. The elevator in the middle can carry out material transfer.

2.2 Construction Sequence

2.2.1 Construction Sequence

When considering the optimal construction sequence, we mainly follow the principle of make full use of existing space and resources.

First of all, we will build a port, so that all the materials needed can be transported to the space station. Our port has a storage room where the material that comes in can be stowed temporarily.

And then we're going to build the central axis. The central axis is the central hub that passes through the Space Station. Having built the central axis, we were able to build other Spaces based on it. The agricultural space and the 0g industrial space inside the central axis are also being built at the same time, with materials produced in the industrial space being used for construction.

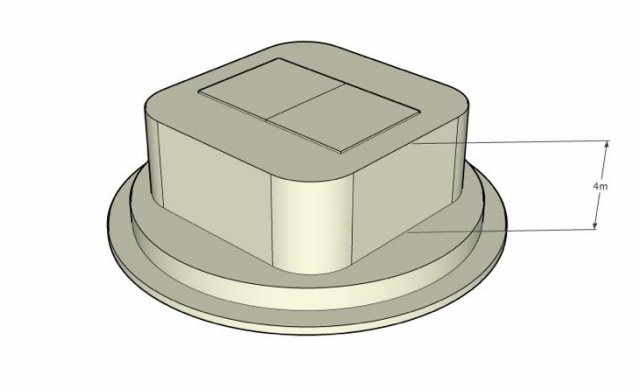
The next one to be built is the solar panels. The solar panels power the space station. As a kind of energy, electricity can help us build the space station more easily. For example, we can use robots to build on a larger scale.

This will be followed by the construction of 1G and 1/6g industrial space. The reason why industrial space is built first instead of residential space is that the materials produced by industrial space can help the construction of space station.

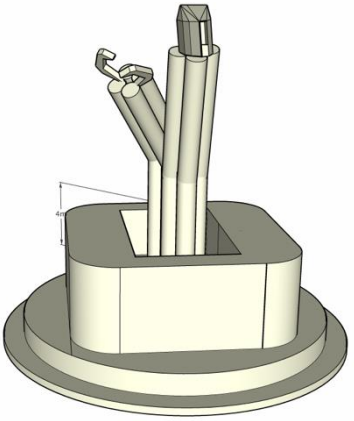
Residential space is the next. At this time, the facilities in the space station are basically complete and meet people's survival needs, so residential space begins to be built.
And finally, engine. Once the engine is installed, the space station is put into orbit around Mars. The reason why the engine is not installed in advance is to save maintenance effort and material resources.

2.2.2 Automatic Construction Equipment

2.2.2.1 Core construction machine

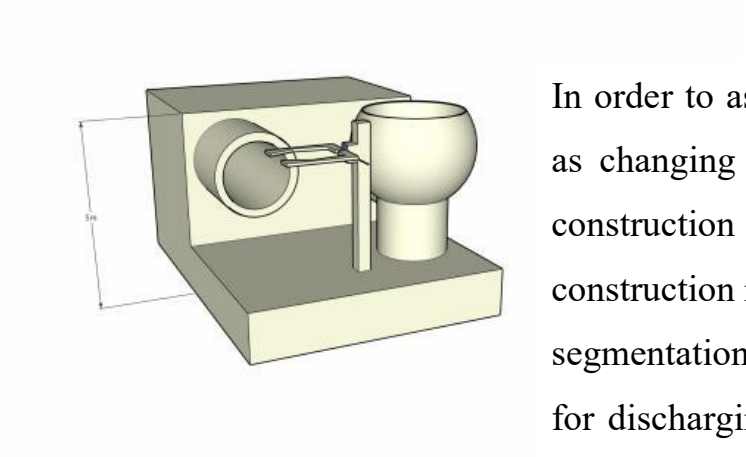


Core construction machine is foldable with the minimum height of 4 meter which is its pedestal.On the top of it is the door that allows the mechanical arms elevating. In order to avoid the erosion from the solar radiation, we use aigis to make this machine which means it is free of radiation when construct the space station.



After the machine is setting up construction mode, two enormous mechanical arms are elevate which can bear weight up to 1million ton. For one core construction machine, it cost about 10,000,000 RMB and weigh about 3 tons.

2.2.2 assistant construction machine



In order to assist the core construction machine such as changing different mechanical arms for different construction and to discharge waste, the assistant construction machine is then designed. It contains two segmentation, one for changing mechanical arms, one for discharging waste. It is also constructed by aigis for same reason and the average cost is 10,0000.

2.3 Construction Material

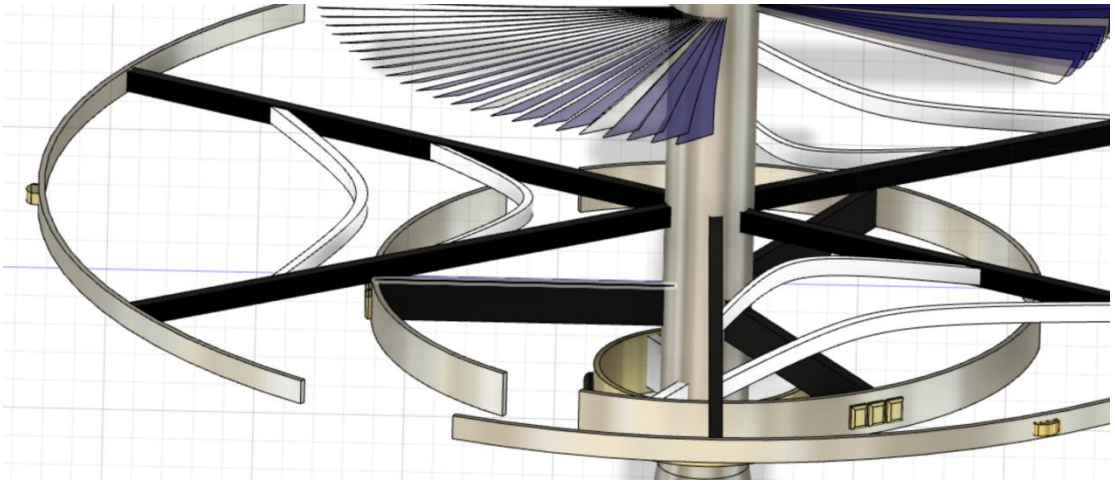
Material	Source	Quantity (t)
Aluminum alloy	On Vulcan	208843
Titanium alloy	On Vulcan	114863.7

As traditional alloys, aluminum alloy and titanium alloy are characterized by low density and high hardness, which are suitable for the construction of space station. At the same time, titanium alloy is very flexible and can withstand high temperature. It is suitable as an external material for heat insulation. They will be produced in our industrial space with 1/6g gravity.

2.4 Delivery and Orbiting

2.4.1 Engine providing artificial gravity

To make the rings turn, we put engine on each ring. These engines produce force in the direction tangent to the ring so that the ring rotates.



2.4.2 Engine responsible for accelerating and decelerating

The minimum speed of departure from the earth：7.9-11.2km/s

The mass of the moon is about 1/49 that of the Earth

GM=v ^2 times r

1/6g 1/49M=v ^2 3/11r

Orbital speed v=root 0.012GM/r=0.09-0.13km/s

Total mass of the space station：491058177.2kg

a=20m/s^2

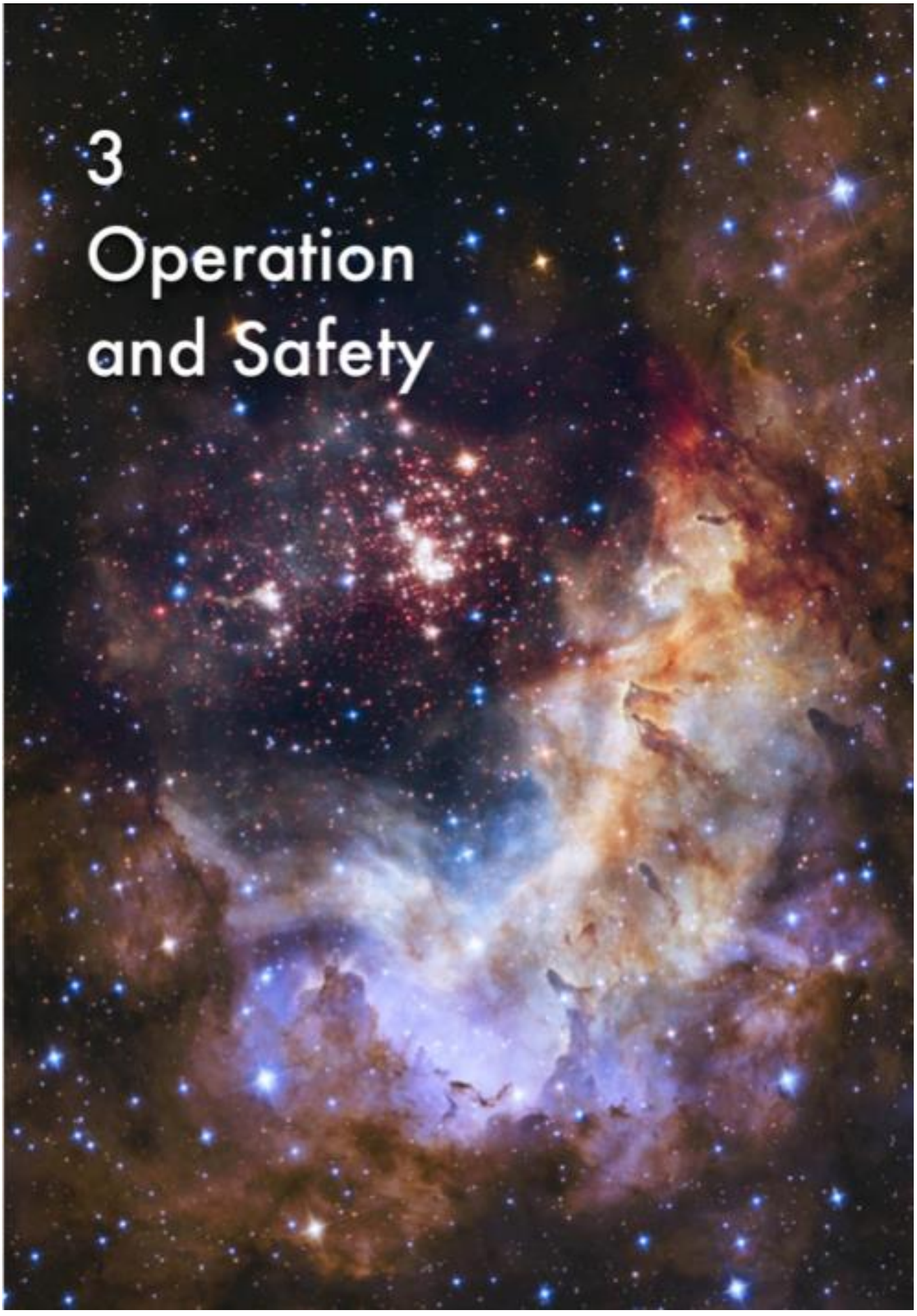
F=ma=2.95x10^11N

Once get into orbit

a=10m/s^2

F= m x a=5x10^9

Total F=3x10^11



3 Operation and Safety

3.1 Atmospheric Management

3.1.1 Agricultural Areas

After we carefully considered the difference of plant growth environment on earth and our space city, we found that atmosphere plays an anchor role in plant cultivation. In order to ensure that the plants in Space City can grow healthily, we carefully set the proportion of air composition in agricultural areas. Our agricultural area has been designed as a circular planting area consisting of several fan shapes, because it can maximum the space, there for we can maximize the crops yield. Also there are intervals between each sector,each intervals is 15 ° with 48m radius. These intervals are used for robots to Irrigate and check for plant growth. In order to let the crops be evenly heated, we used half ring-shaped farm area which is better than rectangular. Thus the sum of all fan shapes is 19371.42 ㎡ ,the volume of whole agricultural is 116228.52m³. In this systems, we requires a high proportion of carbon dioxide, which is considered beneficial for plant photosynthesis and thereby sustains ecology balances.

Agricultural area		
Gas	partial pressure(atm)	Mass(kg)
Nitrogen	6.60×10^-1	1.11×10^5
Oxygen	1.70×10^-1	2.53×10^4
Carbon Dioxide	1.60×10^-1	1.74×10^4
Water Vapor	2.73×10^-3	7.13×10^2
Total	9.93×10^-1	1.54×10^5

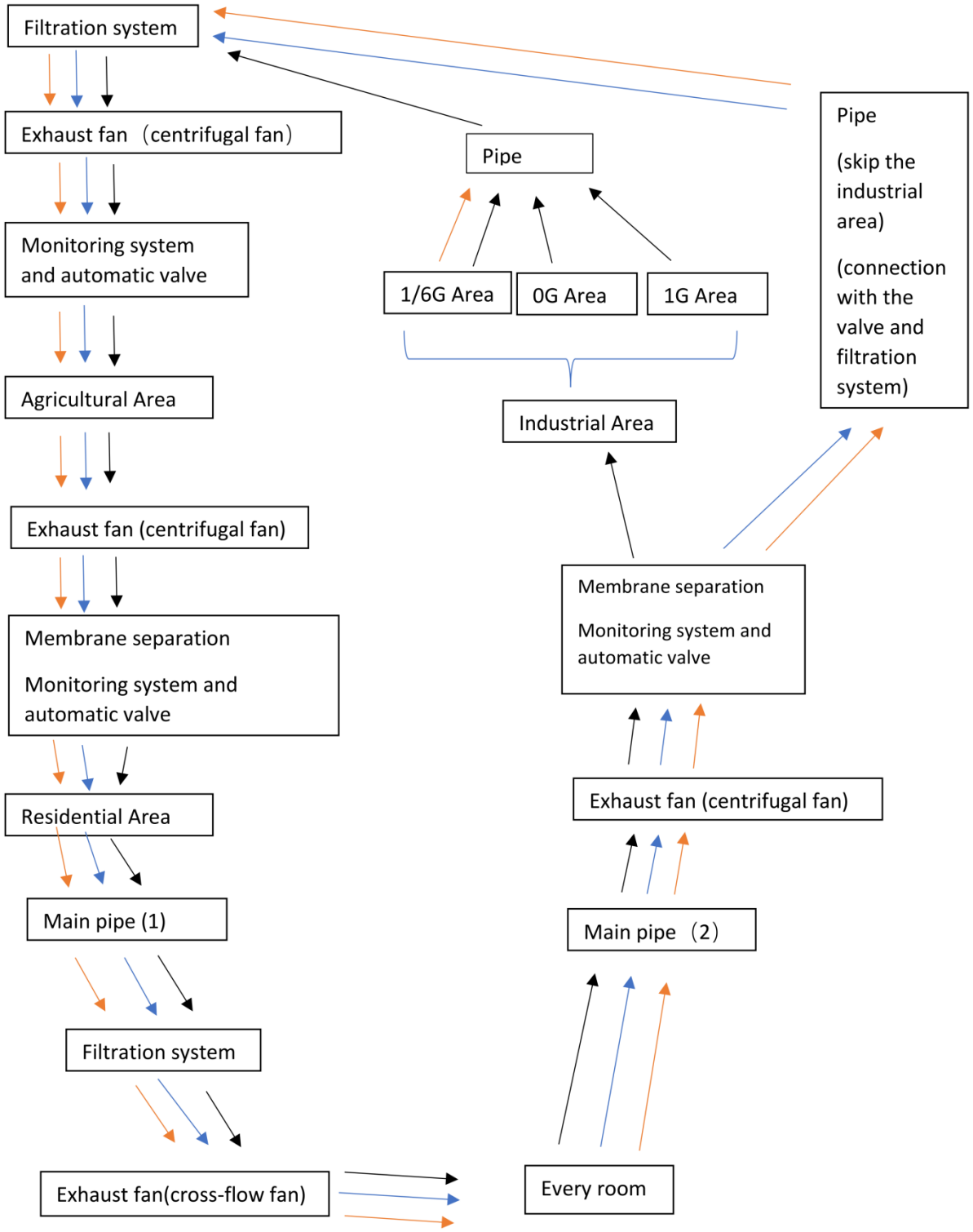
3.1.2 Living and Exercising Areas

We designed three identical parts of residential area, each area of them is 3107.54 ㎡ . The height of our residential building is 4m, hence the volume of living and exercising areas is 37290.52 ㎡. Which are capable of accommodating 1800 staffs and space travelers.

resicendial(living and exercising) area		
Gas	partial pressure(atm)	Mass(kg)
Nitrogen	6.48×10^-1	3.64×10^4
Oxygen	1.44×10^-1	1.14×10^4
Carbon Dioxide	6.46×10^-3	3.66×10^2
Water Vapor	1.66×10^-4	2.25×10^1
Total	7.99×10^-1	4.82×10^4

3.1.3 Industrial Areas

Considering that our industrial areas are essentially used to iron making and producing machines. We set the composition of pressures would be of 10%O_2 and 90%N_2.



Legend		
Oxygen	Carbon dioxide	Nitrogen gas
→	→	→

Explanation

1.Exhaust fan

its function is to give the power or the force to boost air flow.

2.Monitoring system, automatic valve and membrane separation

this equipment has two parts. According to the air standard composition of each areas, the monitoring system is able to monitor the areas' current air composition. If there is changing between current's and the standard. The monitoring system will automatically control the valve to release gas through the membrane separation until the current air composition is equal to the standard.

3.The oxygen in the 1/6G industrial area

In the RFP's background, we have already known that the low gravity unmanned smelting system is used on the moon which is 1/6G there. Also, we knew the dirty snow can provide oxygen. In this case, we use the low gravity unmanned smelting system situated in the 1/6G industrial area to process dirty snow in order to get the oxygen. Later, release the oxygen to the circulation.

4.The separation of three kinds of gas just before going into the industrial area

Because of the superb technologies, the existing of many unmanned machines, we do not provide carbon dioxide and oxygen in the industrial area, only put the shielding gas—nitrogen gas in it. So, we design a separation part.

5.Membrane separation (solid film) (near industrial area)

The aperture of the membrane is generally micron. We set that the membrane and a separator to separate carbon dioxide, oxygen and nitrogen gas. Because we do not need the first two kinds of gases in the industrial area, we separate them going directly to the filtration system. The separator can let the nitrogen gas which It's stuck on the membrane smoothly access to pipes leading to industrial areas.

3.2 Electrical Power Management System

1. Power Consumption Calculation

1.1. Human Living

A maximum of 2000W/person as the power consumption for each human is needed in order to maintain a comfortable and sufficient living condition for residents, including: daily illumination, energy cost of using facilities, and entertainment. As a result, the total power consumption (including illumination, recreation, etc.) for 1g living area would be approximately

$$(1.5\text{-}2)\text{kW/person} \times 1{,}800 \text{ person} = 3{,}600 \text{ kW}.$$

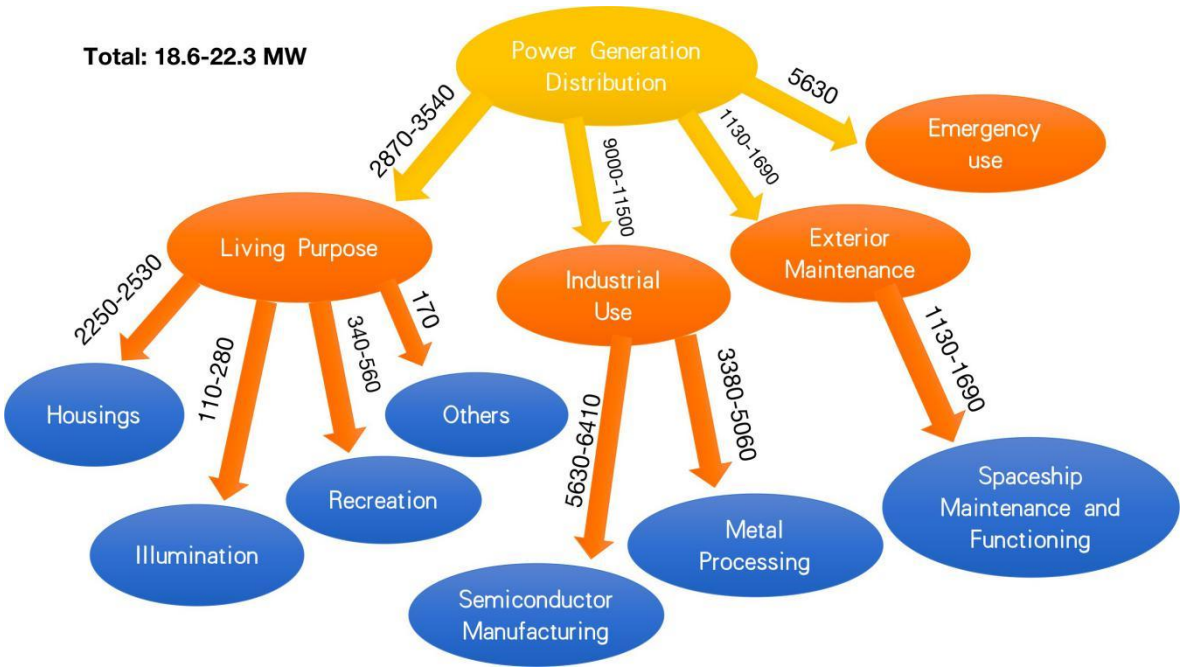
1.2. Semiconductor Manufacturing

Semiconductor Manufacturing is one of the most crucial spotlight on Vulcan, and it is also the most power-consuming one. The raw metal of this semiconductor, polysilicon, is composed of many small single crystals with different crystal orientations. Polysilicon must be melted under extreme high temperature into single crystals before it can be processed into wafers used in semiconductor applications. We have estimated that workers produce wafer at an approximately rate of $0.8m^2/h$, so that the daily consumption of energy is about $3.98x10^{11}J$. Therefore, by converting units, the electricity producing efficiency is 6410kW.

1.3. Power Operation and Management

Elastic Water Allocation (EWA) is a kind of system that meet customer's instantaneous variation in the amount of water consumption. The operating principle of EWA is similar as what we use in Vulcan to estimate the power consumption. If both the residents live in the first and second layer consume a lot of power, our pressure-resistor will detect that and allocate power to that area instantaneously. The following chart (See Chart 3.2-2) illustrates the power generation distribution inside and outside the settlement.

Chart 3.2-2 Power Generation Distribution in . (Unit: kW)



3.3 Water Management

3.3.1 Estimating water cost

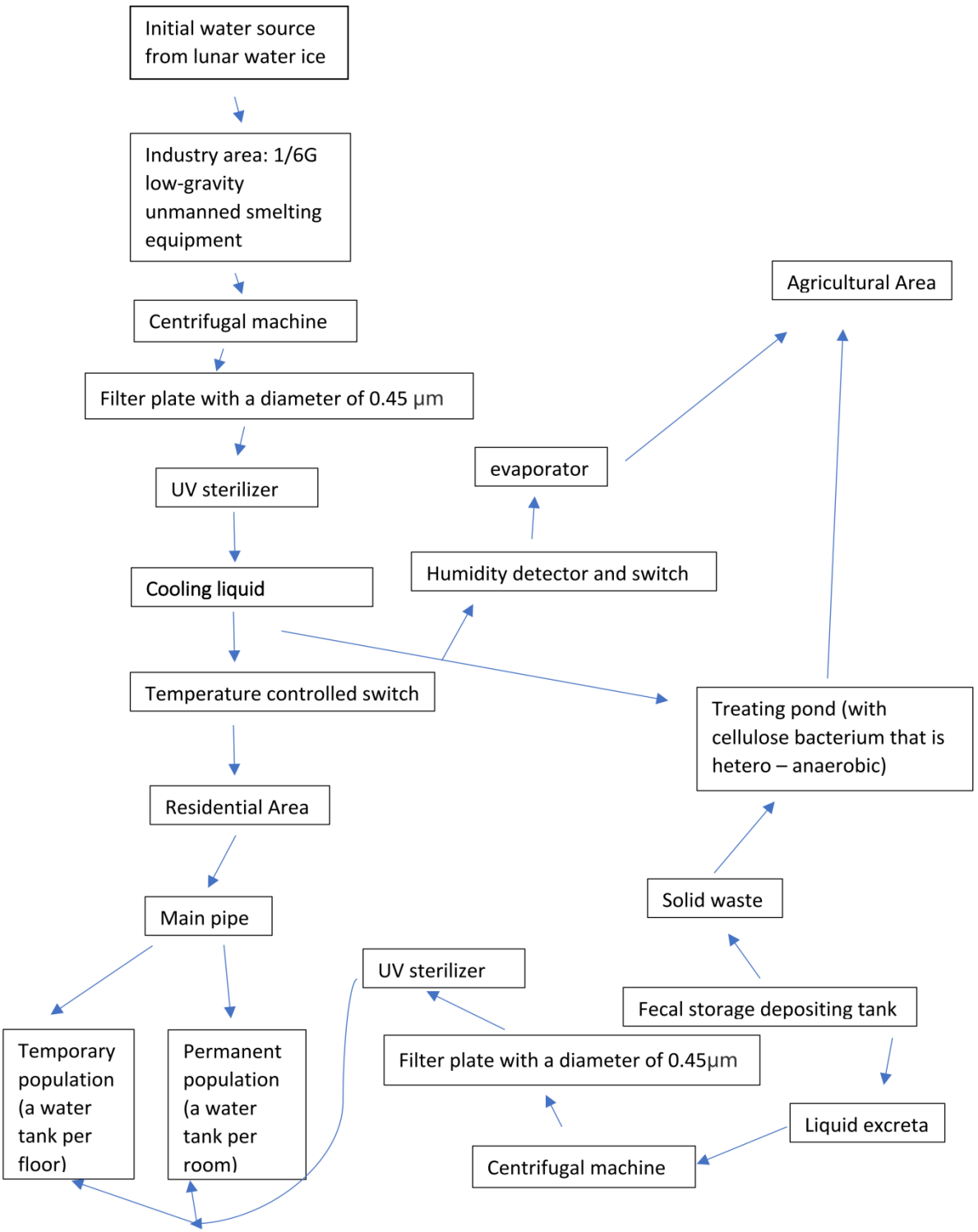
Water consumptions in Agricultural area			
Crops	Potato	Rye	Spinach
Cultivated area (m2)	25200	10500	3150
Water needed for growth in one month (m3)	3780	787.5	591
Total water consumption in one month (m3)	5158.5		
Water consumptions in Residential area			
People	Accommodation type	600 residents	1200 visitors
	Unit water use per person per day (m3)	0.1315	
	Total in one month (m3)	2367	4734
Plants	Area (m2)	150	
	Unit water use per day per meter square (m3)	3.5	
	Total in one month	525	
Others	Water consumption by diluting urine (m3)	1.35	2.7
Total	Having visitors: 7630.05m3Do not have visitors: 2893.35m3		
Water consumptions in Industrial area and Port			

Because water for heat dissipation is still in the water transportation pipe. Although it turns into gas, it can change to liquid water again. There is not significant lose in this part. Also, as parts of space ships' fuel is out of our space city. We do not consider it.

The only fact we consider is the water using for smelting metal(m3): 2000

The total water consumption: Having visitors: 14788.55m3
Do not have visitors: 10051.85m3

3.3.2 Water Cycle Flow Chart

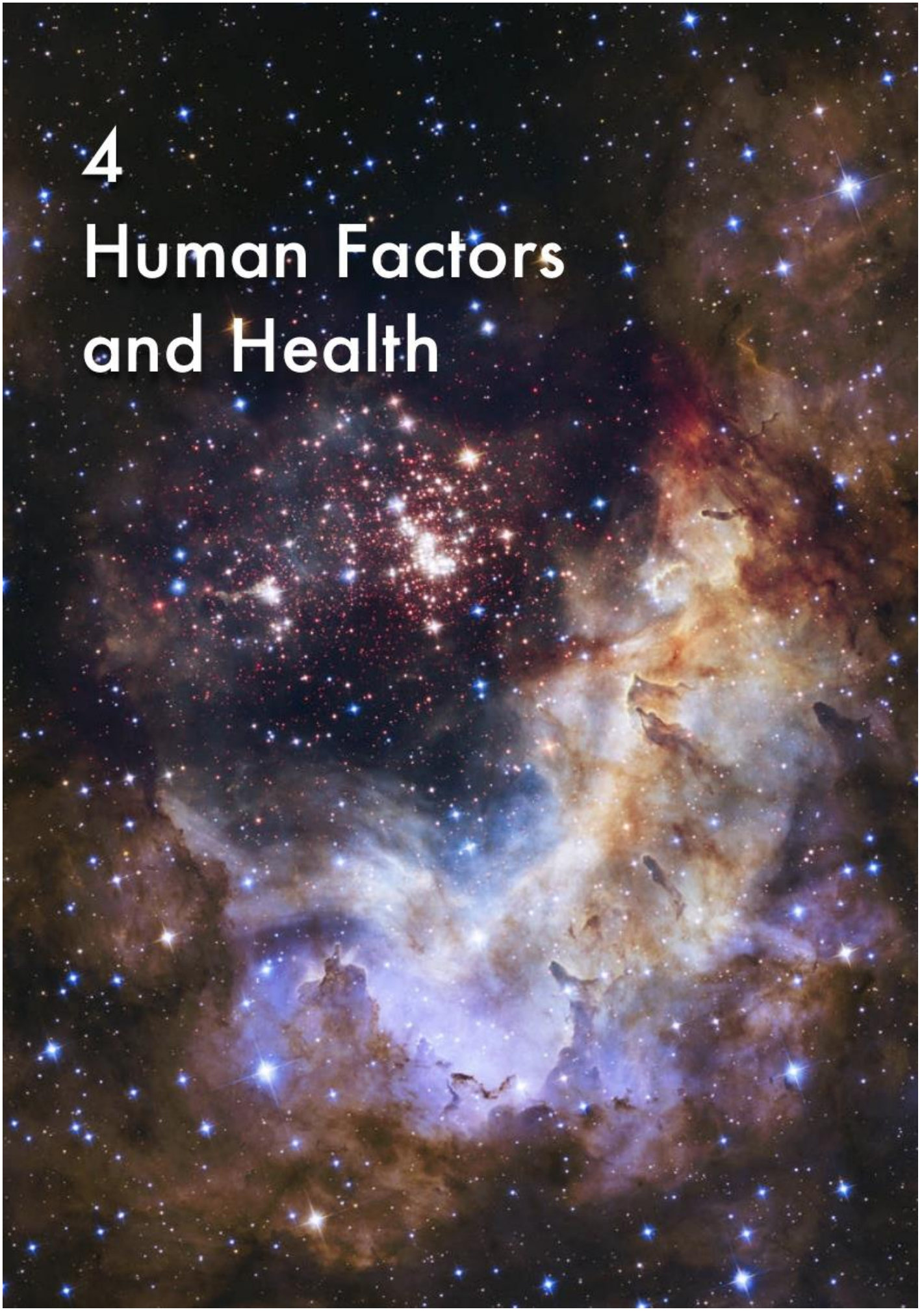


The explanation of water management flow chart

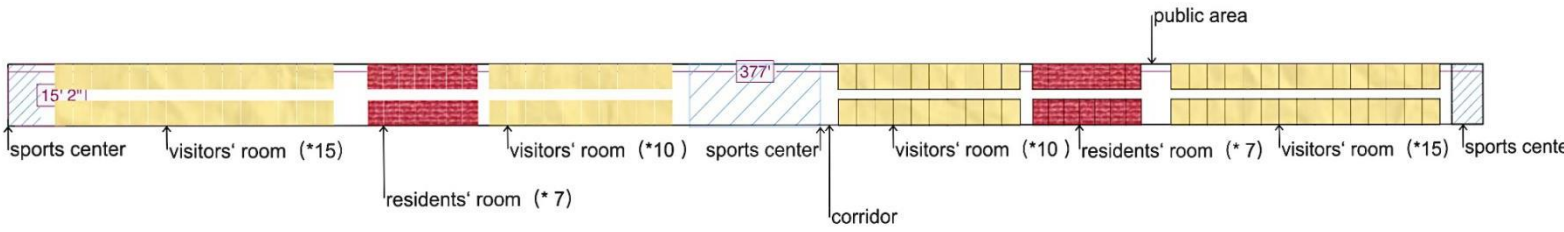
The raw water comes from lunar water ice. Our machine will dig the water ice out and send it to the pipe where they will be sent into the Industry area's unmanned smelting equipment. As soon as the water ice melts, this raw water will refine to pure water by the centrifugal machine, filter plate, and UV sterilizer. Pure water will stay in the industrial area for cooling liquid. After that, a divergent path is placed for diving them into two parts, one for the residential area, and the other is for the treating pond.

The purified water for the residential area will be transferred to its terminal by the main pipe, and then divided into two pipes ended at two separate tanks for the temporary and permanent population. In the residential area, the problem of excreta management is also what we need to concern about. From the fecal storage depositing tank, liquid excreta will go through a centrifugal machine, filter plate, and UV sterilizer. Then, liquid excreta will transfer into pure water and reuse by the resident. For solid waste, they will be transferred to the treating pond, where they will meet the other branch from the industrial area. In the treating pond, solid waste will ferment to nature fertilizer and serves the agricultural area.

There is also one secondary pipe from the mining pipe between cooling liquid and the treating pond, which is for the humidity of the agricultural area. We design a switch for judging whether the temperature is suitable for plants. If it's not suitable, then the switch will close and force the hot water to cool down. As soon as the water is cool down, the switch will open, and water resources will transfer into the agricultural area.



4 Human Factors and Health



4. 1 Residential Space Design

4.1.1 Floor plan

4.1.2 Design for better fit-in

1.Plants:

We will arrange plants at 2.5m intervals in the corridor and choose different functional plants.

This will increase the humidity of the space station (since indoor relative humidity should not be less than 30%; if the humidity is too low or too high, there could be adverse effects on human health) Moreover, it will help clean and regulate air as well as produce oxygen and negative ions. More importantly, it will help add visual fun to the passengers, relieves the fatigue and depression of space travel, and invigorates their mood

2.Carpets:

We will choose and arrange carpets with varied colors and patterns in each room.

Firstly, it will bring comforts and warmth of home to the passengers, beautify the environment, and promote emotional exchange between residents and visitors since they could become topics after dinner to talk about.

Secondly, it will absorb potential noise from space station operation and have good sound insulation effect.

Thirdly, it will have thermal insulation function, so that the temperature maintained by

air conditioning in the space station will not be easily lost.

3.Residents/Visitors accommodation mix:

It will facilitates the communication between residents and visitors and helps residents guide visitors so that visitors can better adapt to the life of space station

4.Sports center (public space):

We plan to place tables and chairs appropriately and some simple beverage machines can be set up in these areas.

It will promote communication between passengers in order to let them better adapt to the boring life on the space station, and slightly improve the space station travels.

Also, tables, chairs, and beverage machines can ease the chatting

5.Lightings:

First, it will strictly follow the three home lighting layout principles: prevent glare (do not dazzle), color temperature consistent, and reasonable distribution. We will make sure that corridor lighting intensity follows earth time to differentiate day and night.Moreover,we will set up a light screen on ceiling to simulate the weather on earth. It will maximize the restoration of living conditions at home and the living environment on earth, so that passengers can have a sense of reality belonging

6.Design of the second floor:

It will divide the rooms into two levels: the upper level is open, and some sofas and small tables could be arranged there.

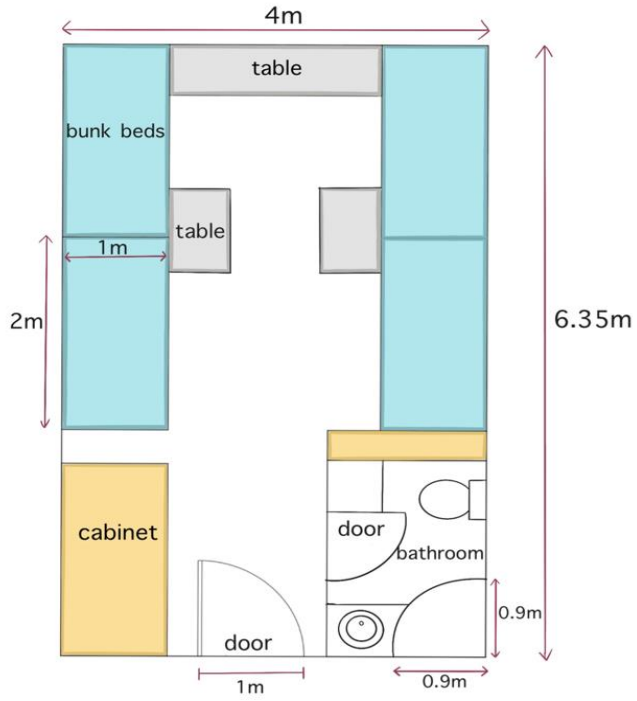
The benefits of this idea are listed as below.

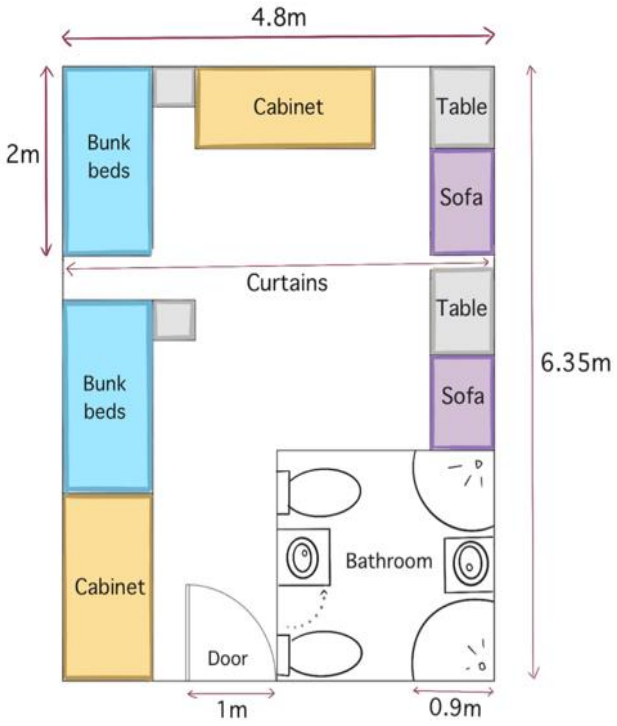
1)Further facilitates passenger communication.

2)Offers an entertainment to the passengers that they can do in their spare time.

3)Brings a comfortable and peaceful environment to stay at.

4.1.3 Interior Design of resident and visitor's housings





Those are the interior designs for resident housings(8 persons per room) and visitor's housings(4 persons per room). There are four bunk beds in resident house and two bunk bed in visitor's room. Each bunk bed can allow two persons to sleep on it and there are small storage cabinets at the bottom of the beds which provide space for people to put their shoes and other objects.

There are many cabinets in resident room because they settle here and need more space to put their things.The curtains in the visitor's room can be moved flexibly and provide

Resident housing *Visitor's housing*

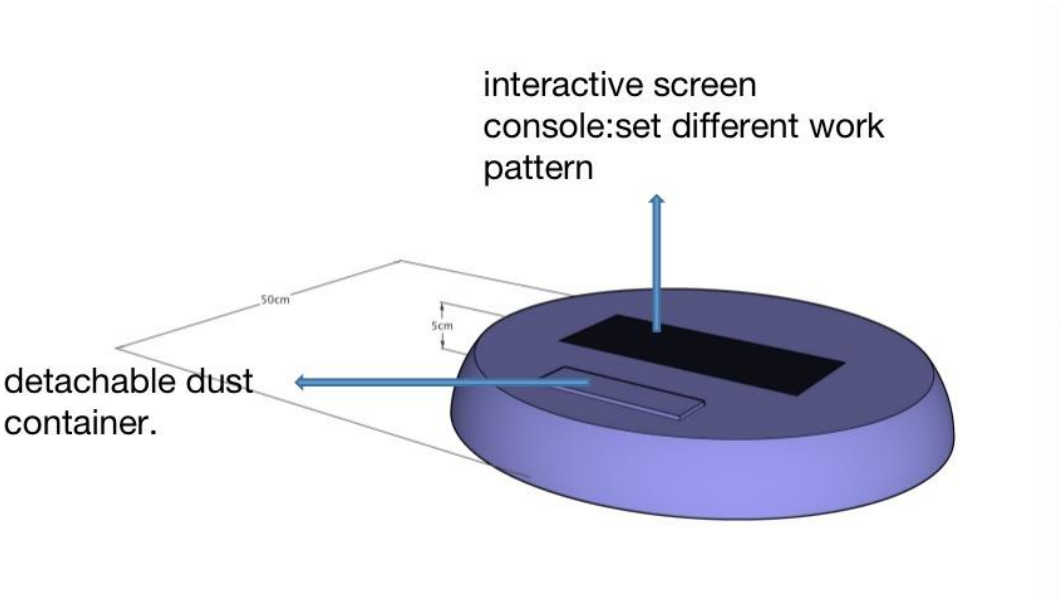
independent space for two groups of visitors. This design not only uses space efficiently but also satisfies visitor’s needs for private space. Sofas are placed in visitor’s room to let them relax.

4.2 Design of automation devices.

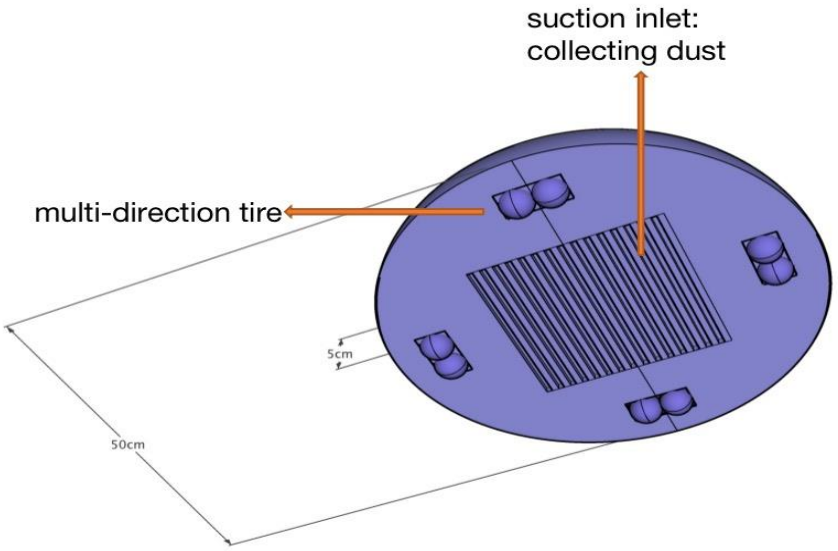
In order to provides a better living condition for workers inside the space station,as well as liberates their hands, automation devices are widely used inside the residential area. These tools can help people inside the station save the time working on daily routine such as cleaning and changing space suit so that they can spend their time on more valuable things.

4.2.1 dust cleaner

Dust cleaner is designed to reduce people's workload on cleaning which is meaningless. The shape of dust cleaner a reversed dish in an effort to make it harmless to human. On the surface is a interactive touch screen which people can use to select different working pattern. In front of the screen is a detachable dust container.



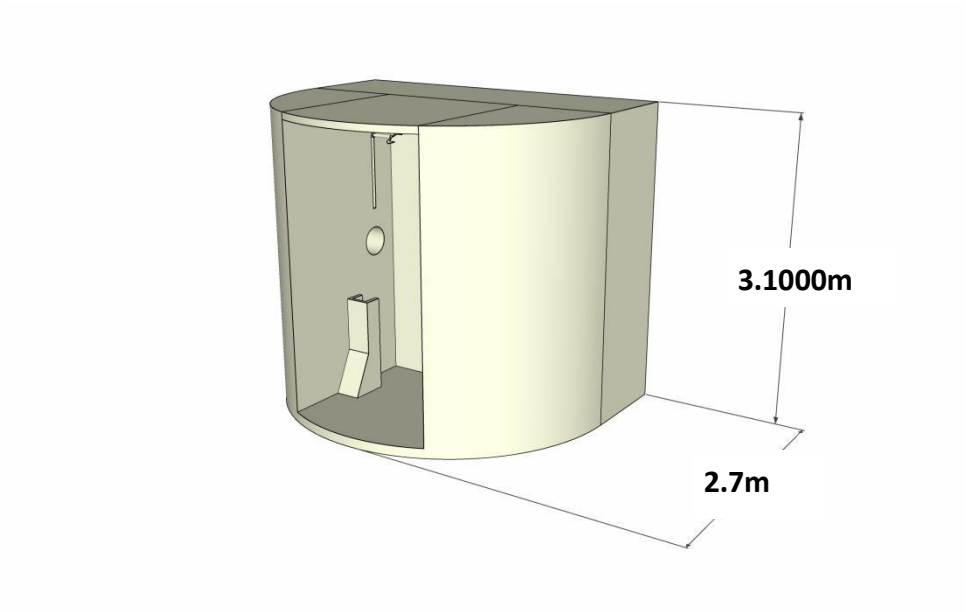
The underside of the cleaner is four pairs of multi-direction tires which can help keep the balance and move to every direction possible. Also,it can help the machine shuffle back and forth in the residential area. In the middle of the underside is the suction inlet where the machine collect dust.



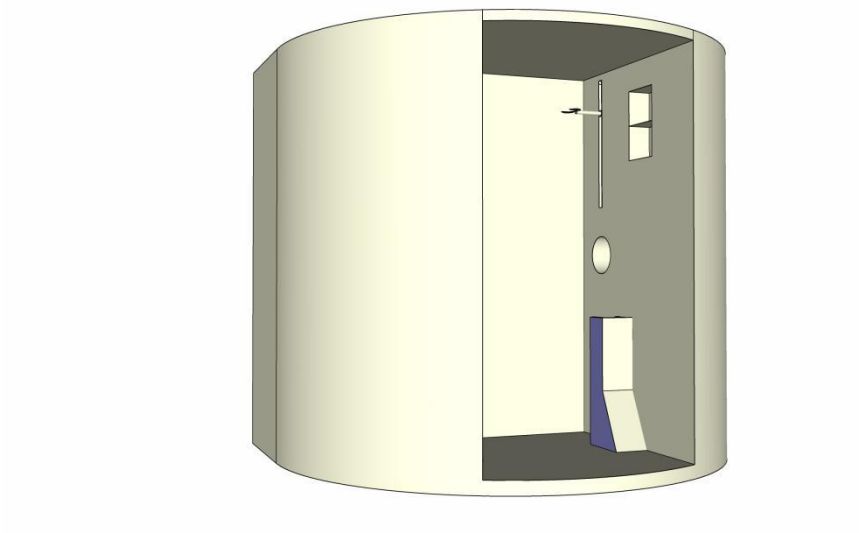
To make the cleaner as durable as possible, we choose to use titanium alloy as material. Also, the cleaner has a radius of 25cm and height of 5cm, which is very suitable under the environment of residential area.The cleaner has a total weight of 1kg and average cost of 2,000 RMB. For residential area, 200 dust cleaner is pretty effective.

4.2.2 space suit wearing assistance machine

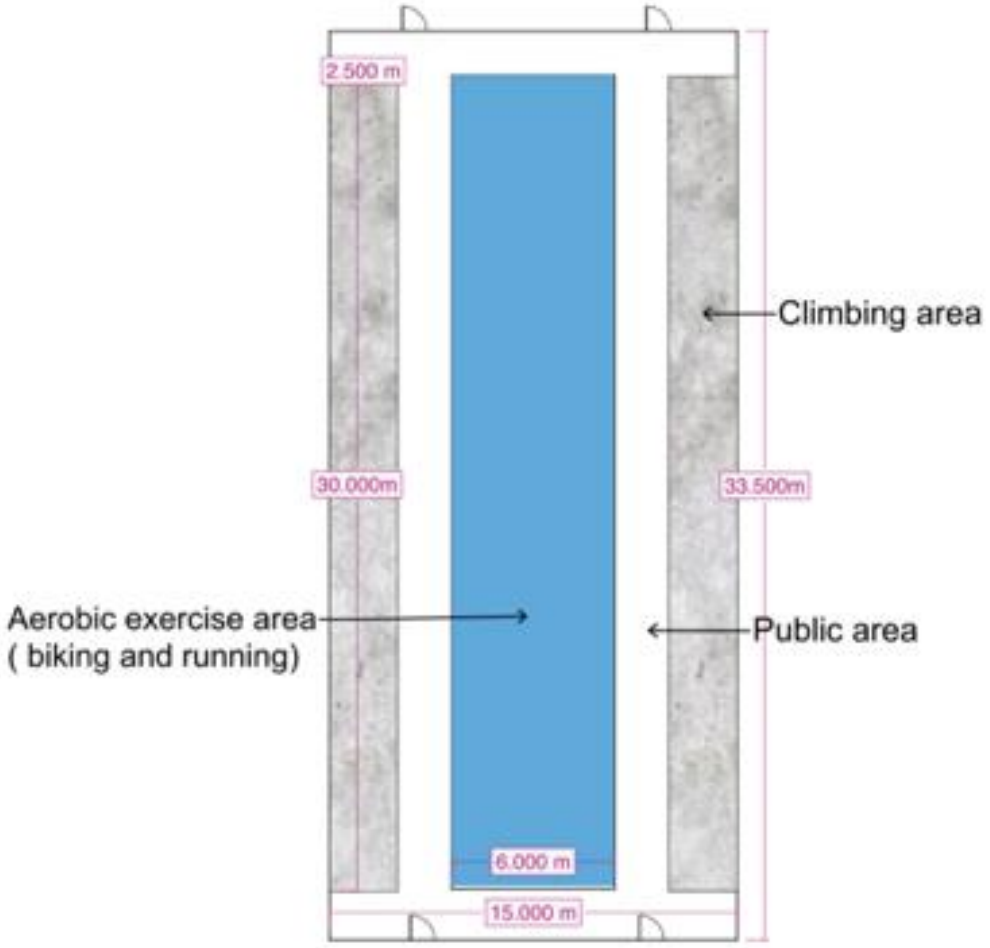
Under the space working condition, changing space suit is very time-consuming. As a result, we designed this machine to save time on doing it. With this machine, the only thing astronauts need to do in order to change their suit is standing in this machine.This machine has mainly three parts: head, arms and legs, corresponding with different parts.

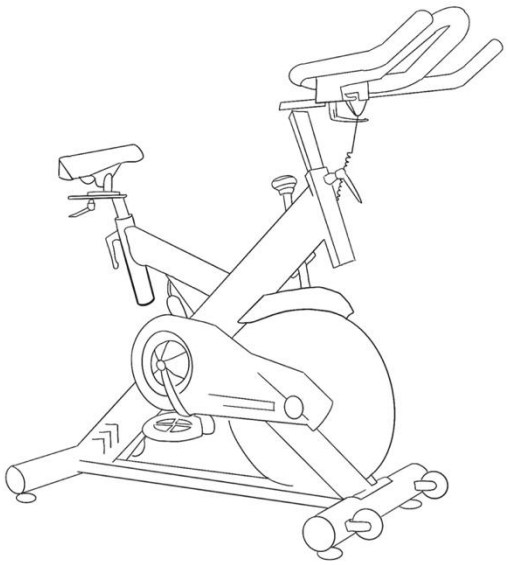


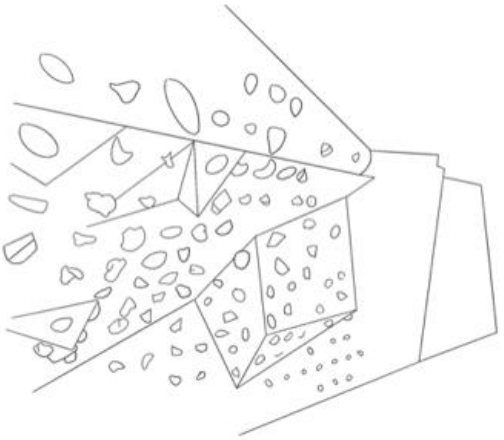
This machine has height of 3 meters and weight of 500kg. For the same purpose of durability, we also used titanium alloy to make this machine. The average cost of constructing such machine is 100,000 RMB. 10 machine is enough for residential area.

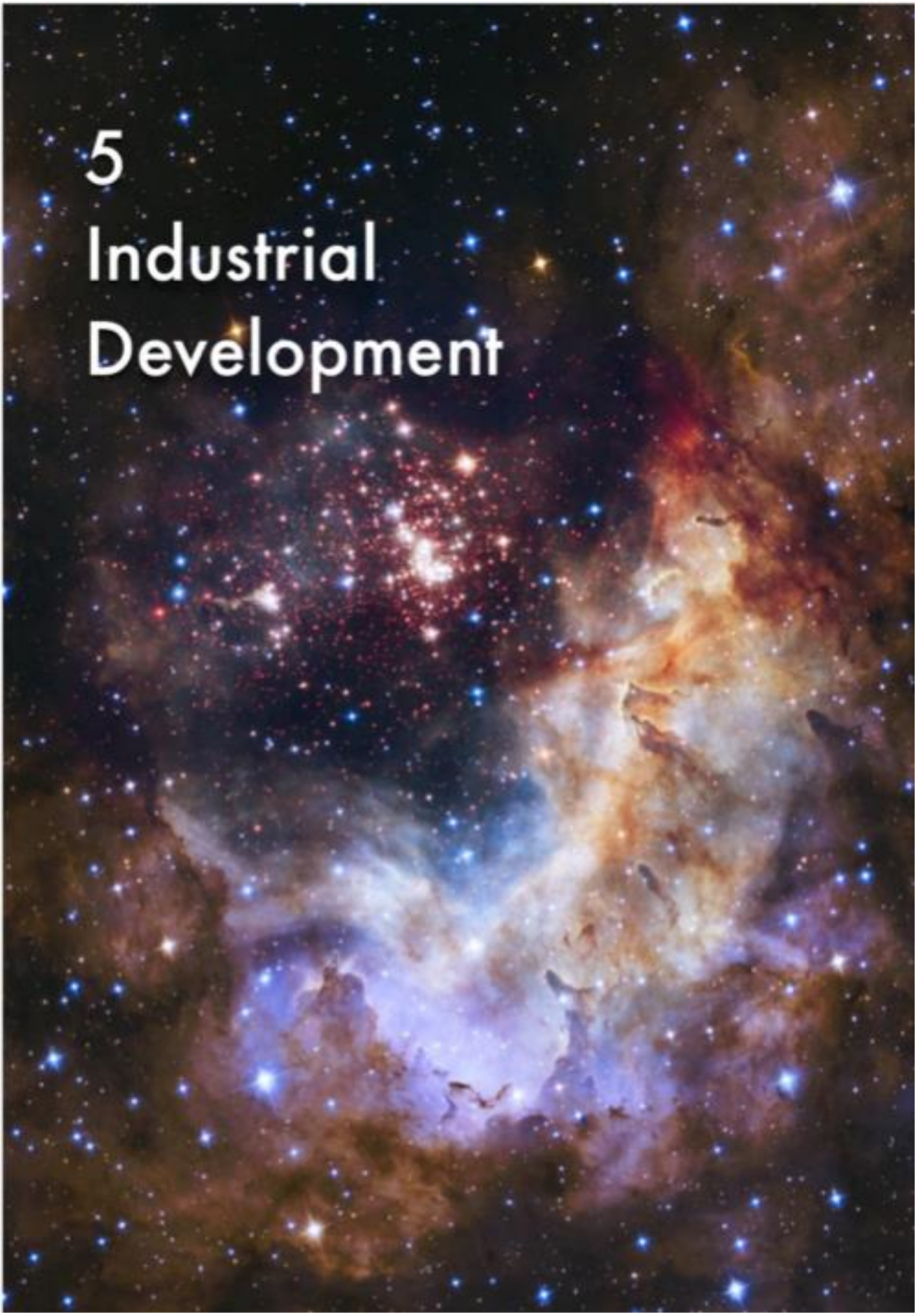


4.3 Activity space



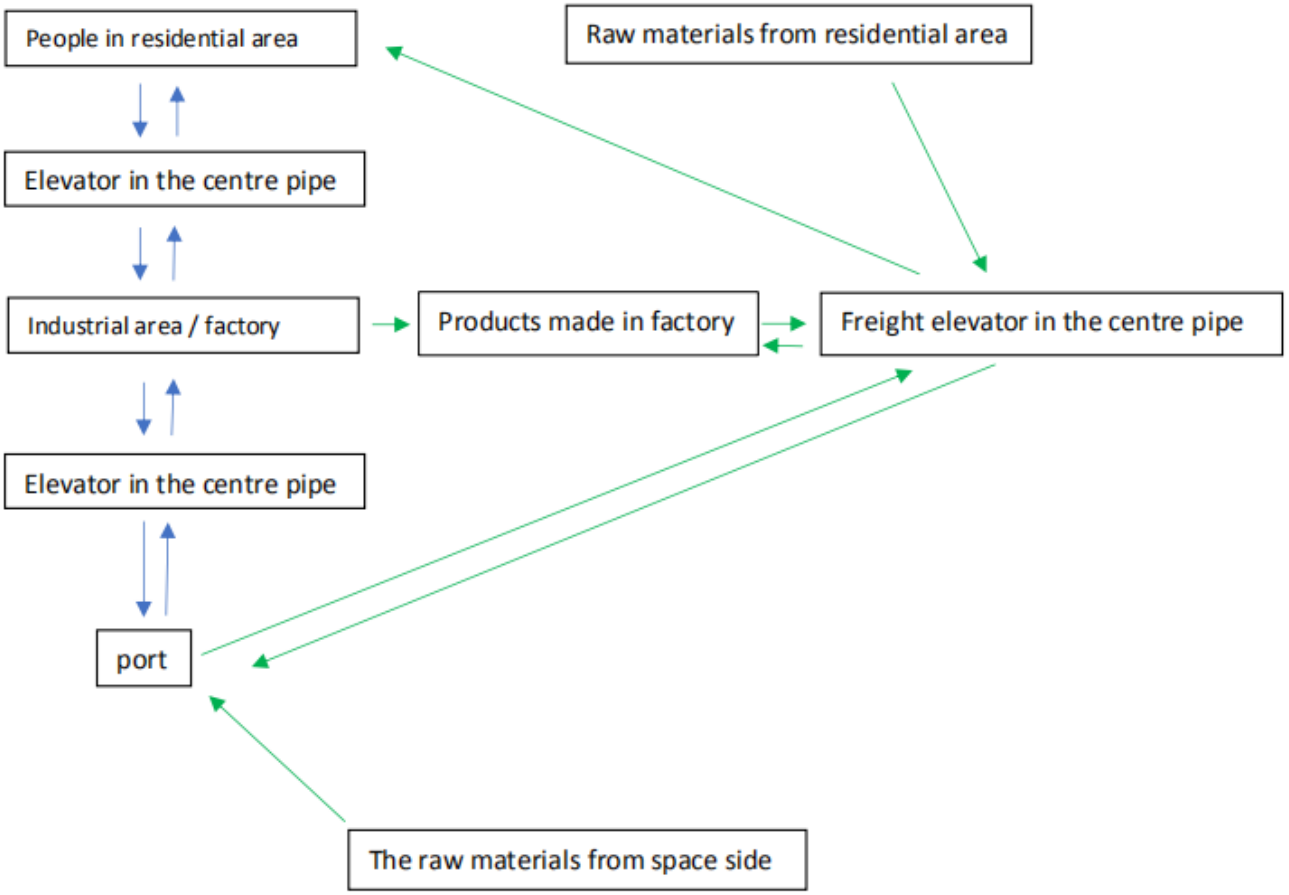






5 Industrial Development

5.1.Design of the Space Factory



Legend	
Transport people	Transport frights and goods

Explanation:

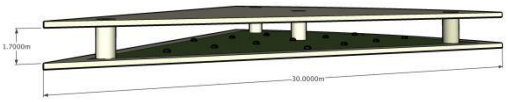
1.The blue arrow in the chart means transporting people. And green arrows mean transporting goods including raw materials and the finished products.

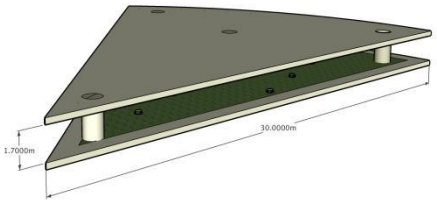
2.People use elevator in the centre pipe to travel between industrial area, port and residential area. The freight elevators are separated from the elevator transporting people, but they are both in the centre pipe.

3. Raw materials from residential area should go into freight elevator and be sent to factory to do the processing. After this, it can send back to residential area or to the port. Otherwise, the raw materials in the space side has the familiar steps with materials in residential area.

5.2.1.1 module of farm

In order to satisfy residents' need for stable food supply in space station. We designed a space farm about 38850 square meter, located at the main axis of space station, to produce sustainable food. This farm is assembled by 112 same module, which allow economies of scale and lowering down average cost.



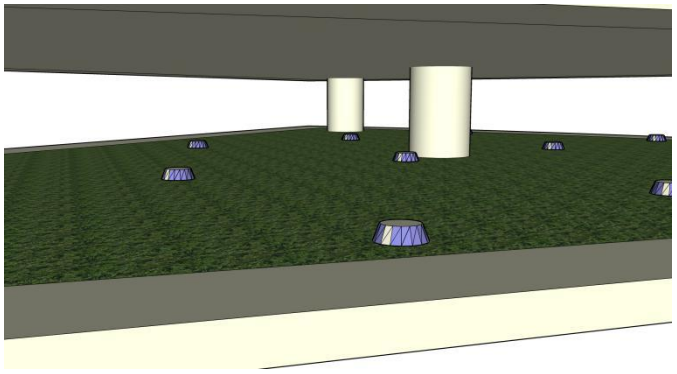


Each module has a shape of 1/8 circle with radius of 30meters and total height of 2.3 meter. There are four pillars propping up the upper penal. Also, the farm employ many automation facility.

5.2.1.2 water sprayer

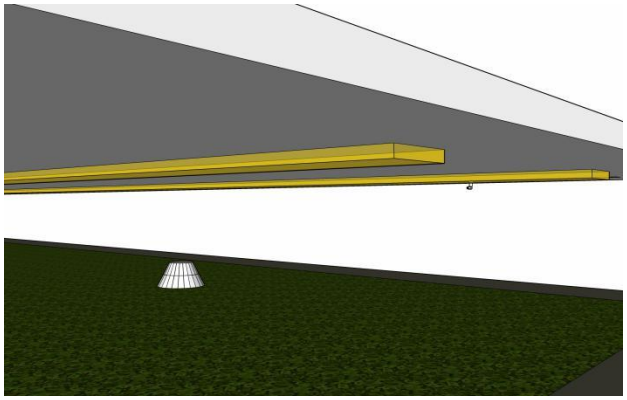
The water sprayer inside the farm will spray different amount of water according to the humidity to refine the plants' growing environment.Also,

the sprayer can identify the optimal humidity and moderate humidity to it.



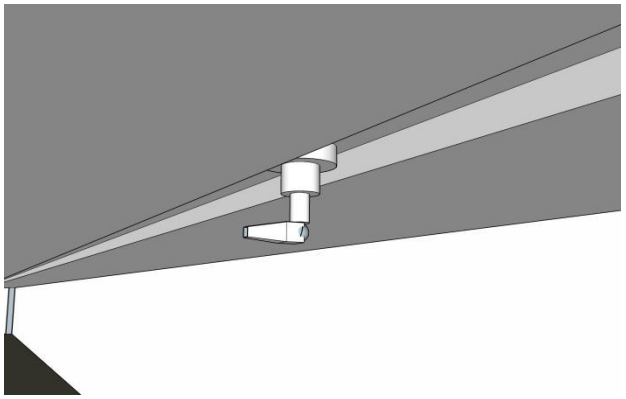
5.2.1.3 LED light bar

The LED light bar is a special design for the plants. It can change the intensity and wavelength of light according to the optimal growing environment for each plants. For 112 module in total, the area of LED light bar employed is about 5000 square meter.



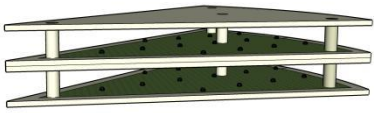
5.2.1.4 laser harvester

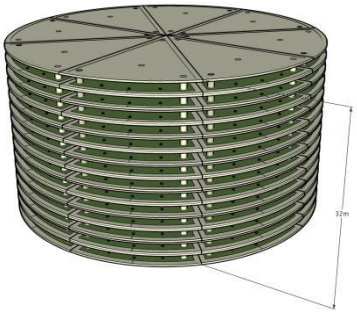
Instead of using troublesome robot to harvest, we decided to use laser harvester. It can moderate the height and the location so that it can harvest the plant everywhere inside the model. Also, it can moderate its intensity to avoid hurt the plant.



5.2.5 assembling module

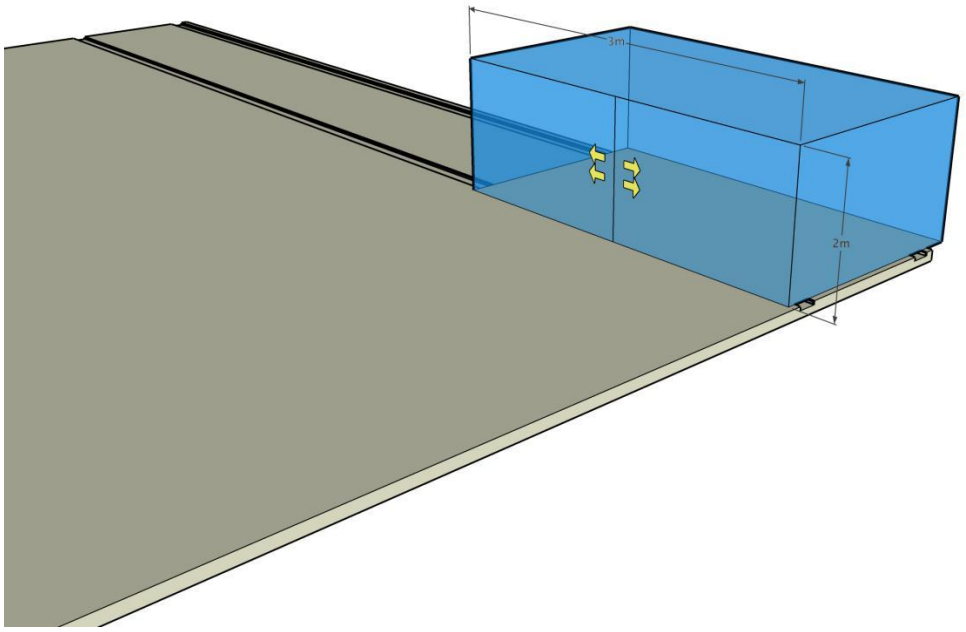
Connectivity is the key feature of the farm module. Simply by placing one module over another can connect two modules together. By repeating this step for 112 times, the ‘farm tower’ of overall height 32.2 meter is finally established

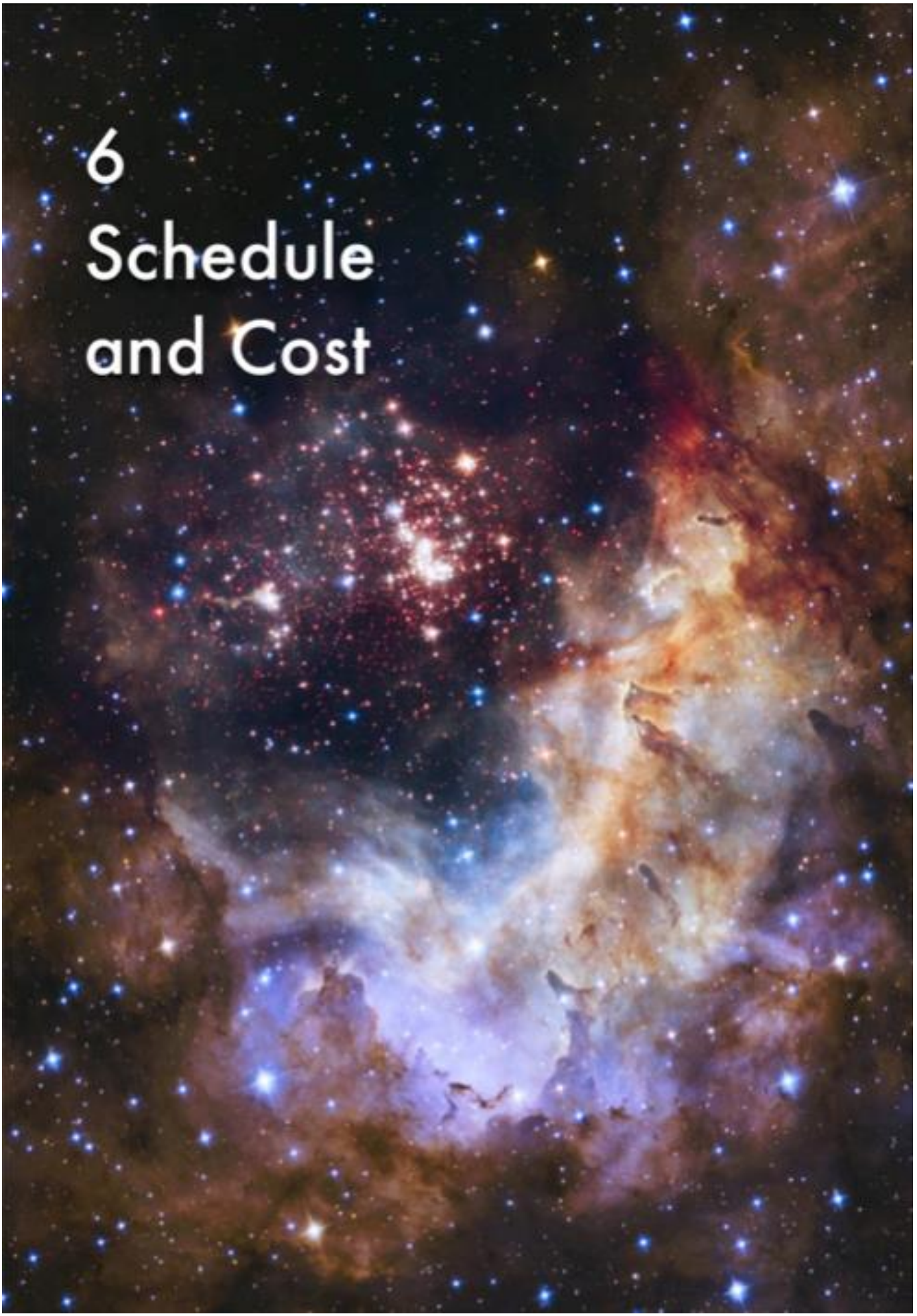




5.3.? Design of port transportation device

In order to provide convenience for transporting freight and people in the port, we designed this device with standard cabin of 3m*3m*6. It has a automatic doors, when it arrived at destinations, it will automatically open. The direction of moving is limited by the concave trail.





6 Schedule and Cost

6.1.Construction Schedule

-

6.2.Cost and Cost Estimates

material	mass/kg（quantity）	purchasing cost/billion yuar	transport cost/(kg*2500billion yuan	total cost/billion yuan
automatic space suit wearing assistance equipment(titanium all	500	0.001	0.001	0.002
module of automatic farm(titanium alloy)	112,000	0.112	0.224	0.336
port transportation device.(aigis)	1,000	0.01	0.002	0.012
core construction device.(aigis)	15,000	0.05	0.03	0.08
assistant construction device(aigis)	2,000	0.01	0.004	0.014
dust cleaner(titanium alloy)	1	0.0004	0.000002	0.000402
potato	50,400	0.0001124	0.1008	0.1009124
rye	5,775	0.0000252	0.01155	0.0115752
water (with visitors)	14,788,550	0.0001591542	29.5771	29.57715915
water (without visitors)	10,051,830	0.0000442073	20.10366	20.10370021
back pressure regulator		0.0002	0.00029	0.0017
maintenance costs				2
liquid nitrogen	1,000,000	0.081	2.5	2.581
aluminium alloy （agriculture）	164,140,499	2.462107485	410.3512475	412.813355
aluminium alloy （industrial）	129,472,549	1.942088235	323.6813725	325.6234607
aluminium alloy （residential）	30,093,621	0.451404315	75.2340525	75.68545682
bunk bed	28,800	0.0018	0.072	0.0738
mattress	3,600	0.00054	0.009	0.00954
quilt	9,000	0.0003	0.0225	0.0228
desk	9,000	0.00009	0.0225	0.02259
chair	9,000	0.00018	0.0225	0.02268
pillow	3,000	0.00006	0.0075	0.00756
treadmill	9,000	0.00018	0.0225	0.02268
spinning bike	900	0.000045	0.00225	0.002295
yoga mat	600	0.000015	0.0015	0.001515
shower				0.472875
toilet	18,750	0.0004125	0.046875	
hand sink				
washing machine	216	0.000036	0.00054	0.000576
synthetic plastic	2,400	0.0144	0.006	0.0204
total cost				869.6220325