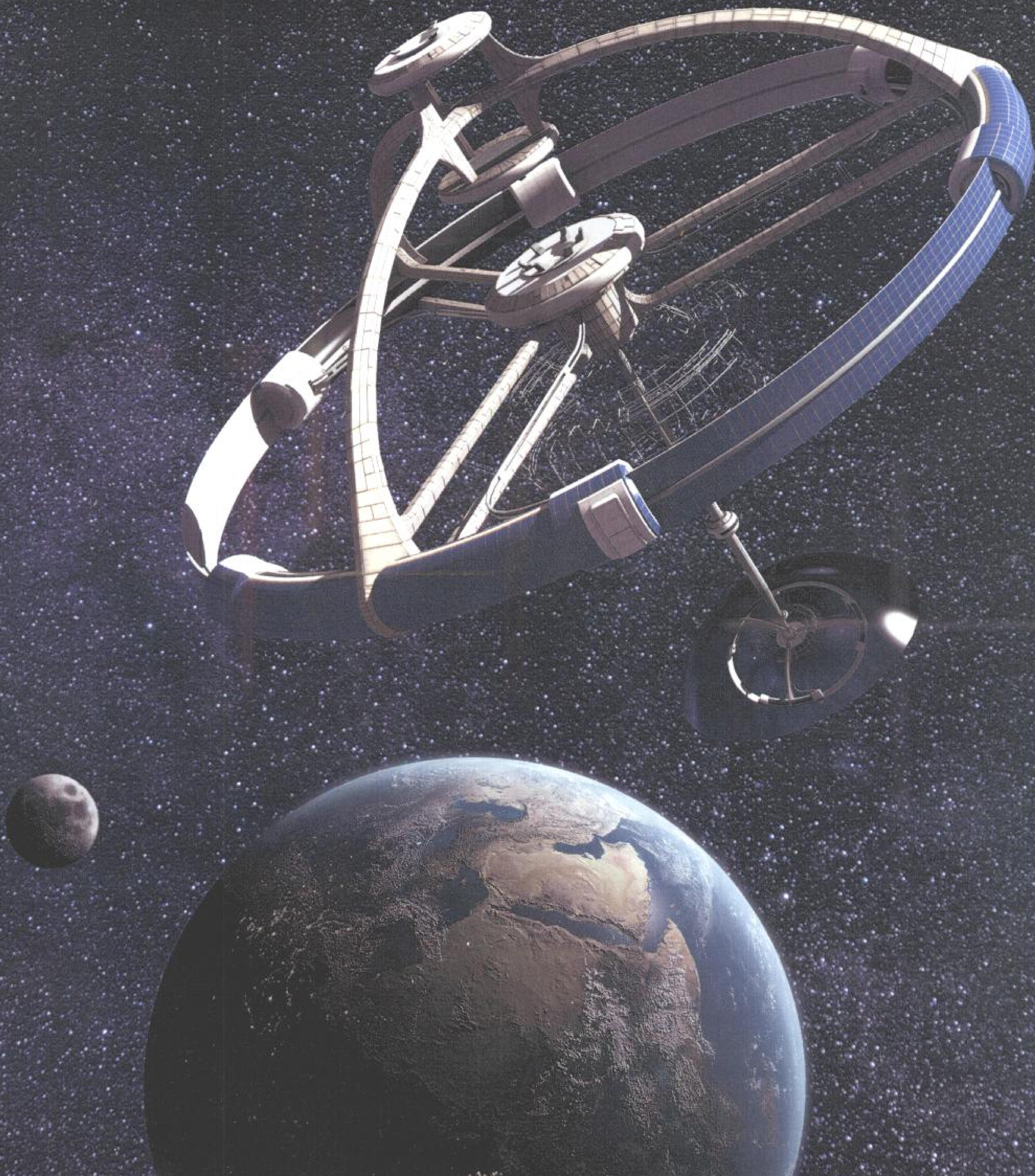
BELLE-β-VISTAT



Student Research Center of Alumni Academic
Foundation of "Mircea cel Bătrân" National Collegium
Constanţa, Romania 2008

SUMMARRY

1.1 Basic requirements

Our company receives the contract for the building of another space settlement around Earth in year 2028, and will be fully operational by 2038.

The settlement will be completely self-sustainable in terms of resources, and furthermore an important all around production unit. Its building process is also innovative, as it will basically build itself, from a preassembled central core part. The materials needed for its completion are also partially obtained on orbit, with Foundation Society's help, from mining operations on a pre-existent ferronickel asteroid captured in L4.

Bellevistat is the main space manufacturing center in Earth's orbit, and takes advantage of the opportunities provided by Near Earth Objects. The settlement uses its automated systems for harvesting materials from other captured asteroids and from the Moon. Bellevistat offers docking facilities for spacecrafts, and represents an important pillar in manufacturing and refining for the purpose of terraforming the planet Mars.

Bellevistat, the second space settlement in Earth's orbit is meant to become a highly efficient commercial center and a very popular tourist destination. It offers beautiful views inside the settlement and to outer space. The settlement can also act as a "training" center, a place where people will get used to living in space, in space settlement environment, a very useful experience for further similar operations and offer the possibility of expanding human population in outer space.

2.0 Structural Design

2.1 Exterior configuration

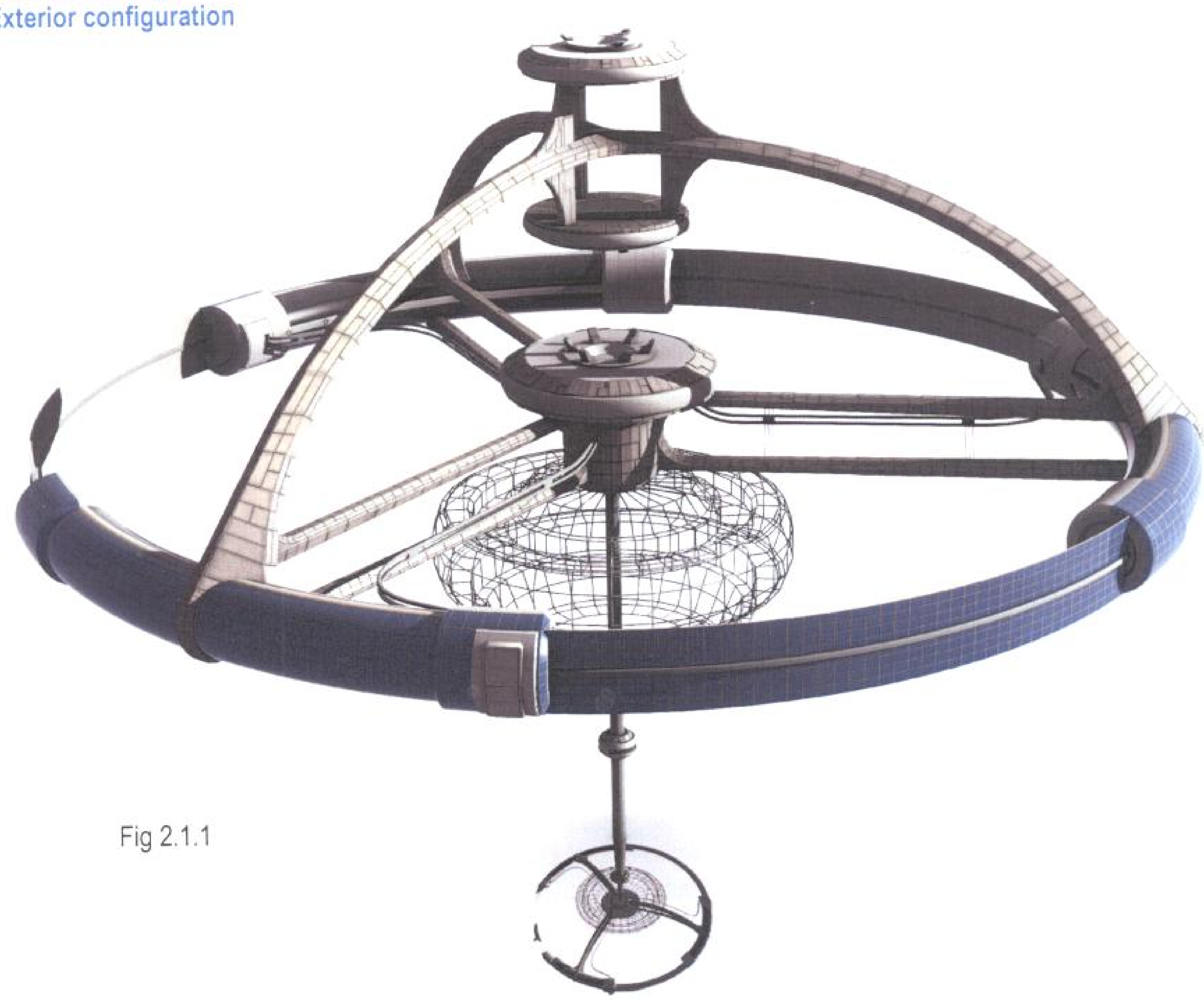


Fig 2.1.1

In developing the exterior design of Bellevistat, our team took into account the main needs the design must fulfill in order to offer its residents an almost Earth-like environment and accomplish its purpose as the primary manufacturing center on Earth orbit. After complex analysis regarding the need for artificial gravity, the power requirements, being a heavily industrialized settlement, protection against the cosmic hazards, radiation or impact with other orbiting objects, we reached the conclusion that the most effective shape of the settlement is the torus, which is also easily sectional, offering multiple possibilities of varying the design according to the criteria mentioned above.

Thus, the torus is divided into three **residential segments**, each of them having two other **smaller segments** at either end. The residential torus segments host, at the main level, the resident population, and below this level, the volume is allocated to the basic maintenance of the station, the construction and development of various robots necessary for upholding some of the torus segments interior and exterior operations, depository areas, basic manufacturing of clothing and food, etc. The smaller torus segments are designed to support the agricultural needs of the settlement's residents, and also offer recreational areas and peripheral launching space ports. These space ports take advantage of the settlement's inertia, so that space vehicles are launched having the peripheral speed of the settlement. These vehicles are transported from the

Central Space Port, through the spoke's transportation system, or from the two upper ones through the "arms". We choose to build torus segments because this allowed the settlement to have a larger radius, thus increasing the "small g" central spread, and minimizing the materials used for the construction of the settlement, using much less quantities than by constructing an entire torus, and still offering spacious environment to its residents.

The lack of gravity can have serious psychological, and physical effects, like bone damaging, insufficient blood flow to the lower parts of the human body, so for permanent inhabitants in space some level of artificial gravity is required. We provide artificial gravity by rotating the settlement around its central axis, creating a centripetal acceleration that for the settlement's residents resembles, to some degree, gravity. At high rotation rates the Coriolis effects become noticeable and can pose serious problems to the adaptation of the human mind, creating motion sickness, called "Bellevistat syndrome". Rotation rates below 1 rpm (rotation per minute) can ensure livable conditions at which the human mind can surpass these effects.

Three engines with movable thrusters placed on the periphery of the settlement, near the space launch ports, bring the settlement to a rotation motion around its axis with corresponding parameters, and correct it when necessary, so that inhabitants don't experience g variance.

For Bellevistat settlement the habitable level is at a distance of $R' = 3080m$ from the central axis, and we can simply calculate the frequency of rotation (υ), by acknowledging that the centripetal acceleration at that level must be $g = 9.81m/s^2$.

$$a_{cp} = \omega^2 R' = 4\pi^2 \upsilon^2 R'$$

$$a_{cp} = g$$

$$\upsilon = \frac{1}{2\pi}\sqrt{\frac{g}{R'}}$$

$$\vec{F}_{Cor} = -2m\vec{\omega}x\vec{v}$$

So putting in the values in the equation, we find that $\nu \cong 0.54rpm$ (corresponding to a period of T=111s), which according to those stated above, is a solution which is in the criteria range. For example a man with a mass of 80 kg travelling with a speed of 2 m/s parallel with the settlement's radius feels a Coriolis force of 18.1 N, whereas the centrifugal force he feels is 768.9 N.

Radiation, the main form of "space weather", is energy that travels by electromagnetic waves (gamma rays, X rays, ultra-violet rays) or through particles like protons, electrons, neutrons, helium nuclei and other heavy nuclei. Ionizing radiation is a type of radiation which consists of high-energy bundles (high-energy photons, high energy protons) that can rip off bound electrons of their atoms. This kind of radiation is particularly dangerous to the unprotected human body, being able to penetrate through skin, damaging living cells, raising the risk of cancer or even causing mutations of the genes. Therefore radiation protection is essential. Due to the technical difficulties in setting up an active shield, our company chose to protect the settlement through a passive shield, made of hydrogen-rich material (very efficient against high-energy protons, neutrons) and layers of dense materials for stopping gamma rays.

The **0g Outpost** is a sphere placed on the central axis of the settlement (where the pseudo gravity created is very small), connecting the mirror with the Central Zone. It hosts 0g Labs used for different experiments regarding how different chemical or physical processes behave in a 0g environment, and a variety of recreational areas. It also hosts an Observation Area, which has a rotating movement with the same frequency but in the opposite way the settlement rotates so as to remain stationary with respect to the stars (except of course the orbit motion). This unit is pressurized.

There are six **spokes**, made of steel-nickel alloy tubes that connect the torus segments with the Central Zone. They serve a double purpose: to ensure the strength required to withstand the centrifugal force that acts on the torus segments, and to transport various ships or internal transport vehicles from the torus segments to the Central Zone and vice-versa.

Three **arms** support Space Ports A and B, functioning also as docking and launching bays in their lower levels. These arms are also used as thermo-regulators for the residential torus segments. They are covered in various layers of special paint, which allows various ranges of frequencies at which heat can be radiated into space (in space objects reach their thermal equilibrium when the total power radiated equals the power absorbed). When there is a need for lowering the temperature, layers that allow a wide range of frequencies at which heat can be radiated are exposed, and when there is a need for raising the temperature, layers that have a narrow band of frequencies at which heat can be radiated are exposed.

A total of 7 widely separated space ports are found on Bellevistat, adding to the volume in the arms used for docking and launching ships. There are 4 docking and launching space ports on the central axis: **Space Ports A and B** and **Central Space Port C** are used for commercial purposes, while the **space port in the mirror** is used for industrial cargo ships and research spacecrafts. The other three are found in the small torus segments, and primarily used for launching.

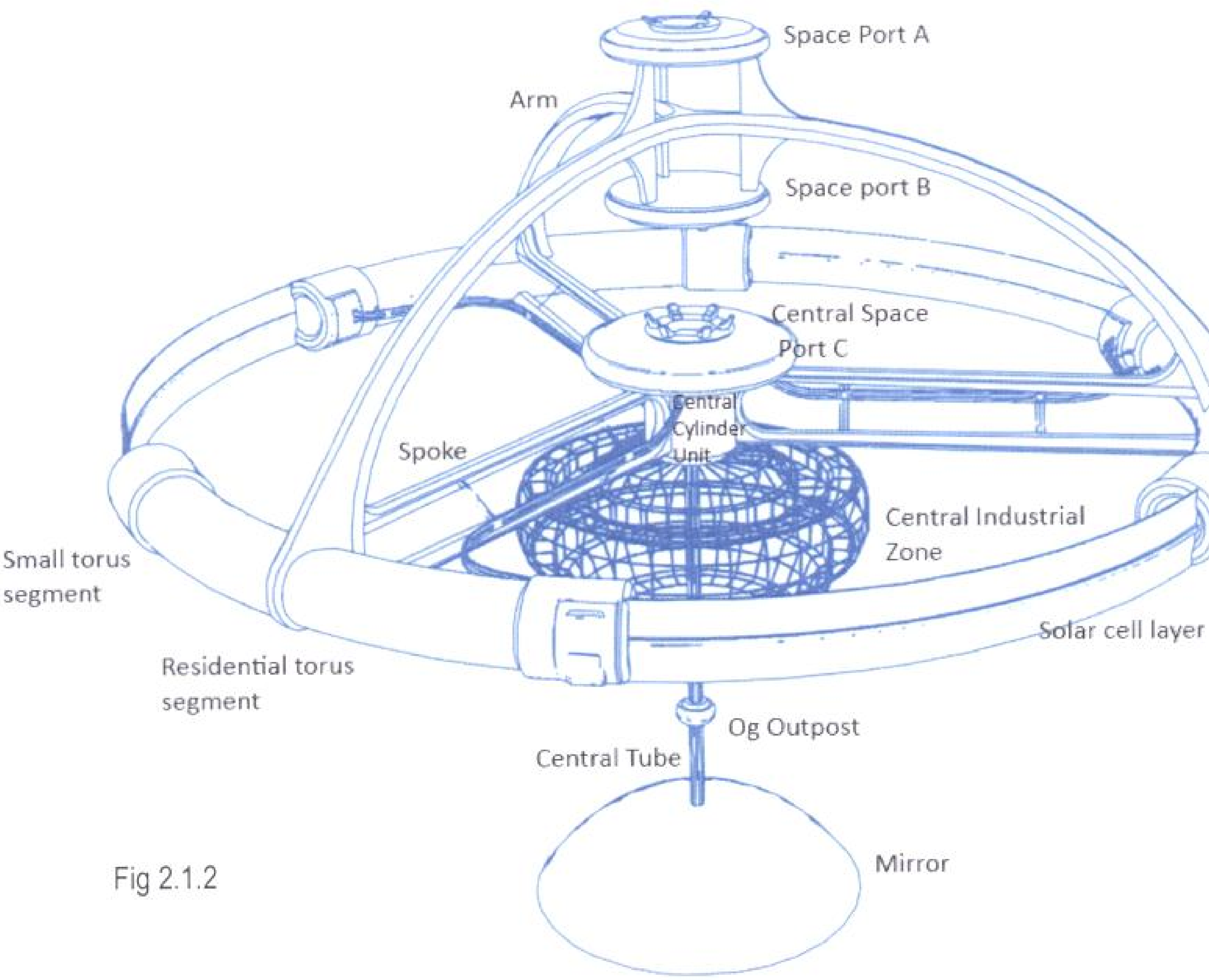


Fig 2.1.2

On the center axis, there is a **Central Cylindrical Unit** which is used to redirect incoming transports from torus segments. It is also used as a robotic management area, medical center, fire station, etc. This Unit is pressurized in certain levels to increase security, since inhabitants use it very often.

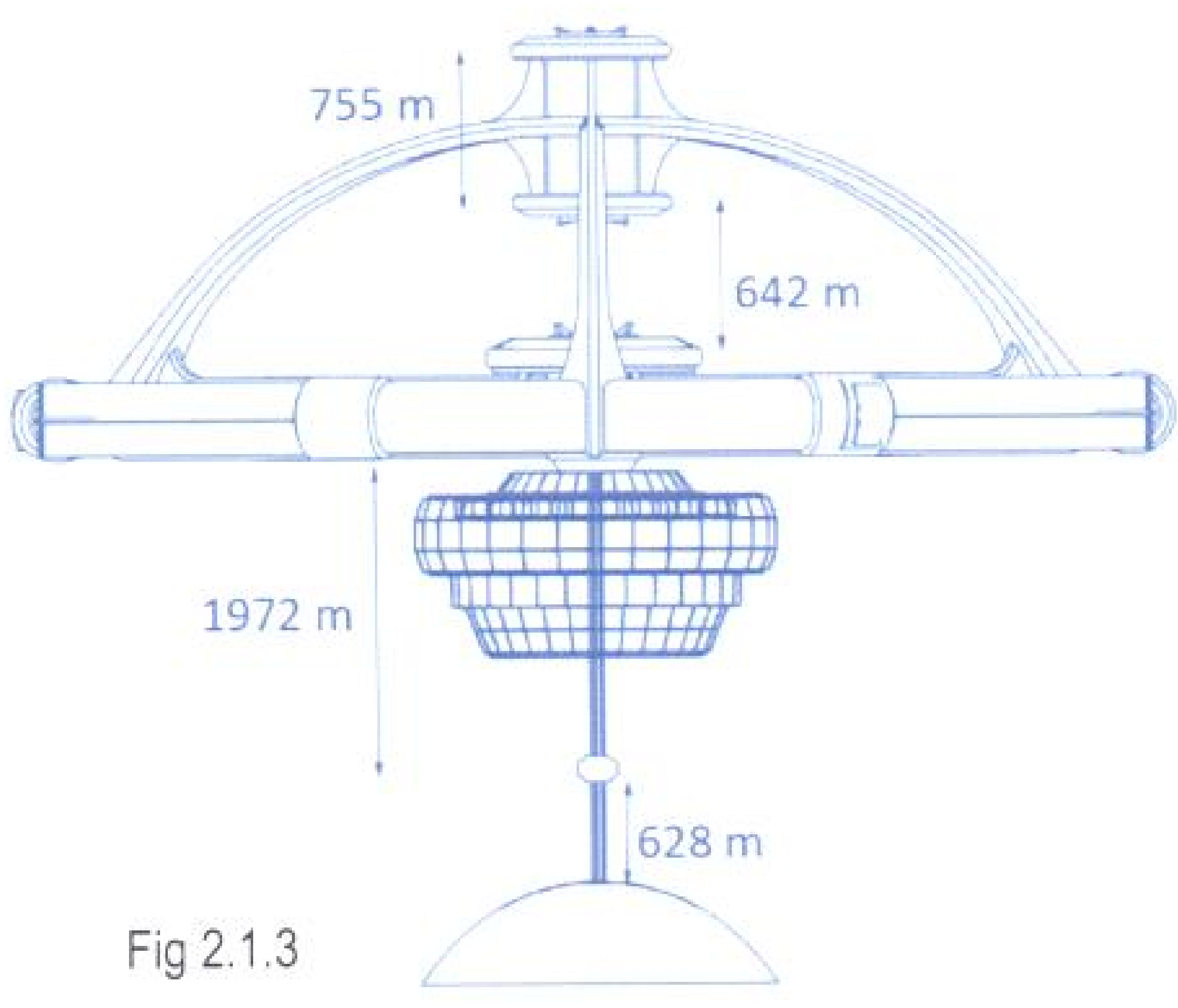


Fig 2.1.3

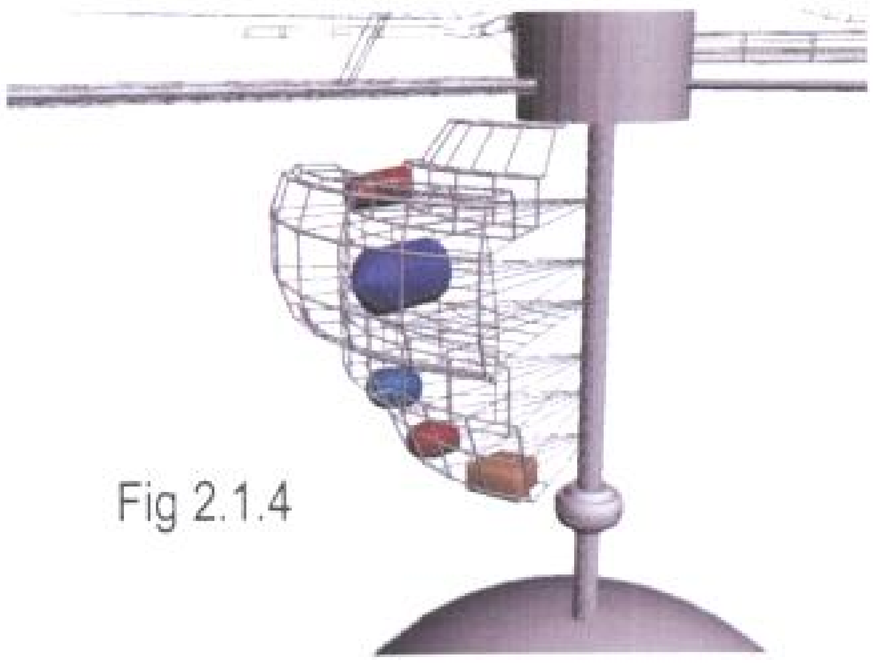


Fig 2.1.4

The **Central Industrial Zone** surrounds the **central tube**, where the gravity created by rotating the settlement is very low, thus facilitating manufacturing, and offering the conditions for creating objects in low gravity and vacuum environment, such as nanobots. It has a highly modular structure. Initially a structural framework is built, made of beams of the same material as the resistance framework of the station. Because we have anticipated the limited need for pressurized areas in this heavy industry zone, this structure is not wrapped with material and pressurized as a whole. Instead, the beams form a radial 3-dimensional structure around the tube, of 1000 meters in length, made in such a way that the spaces between the beams vary according to their destination. There are industry production and manufacturing spaces which vary slightly and are placed further or closer to the central tube depending on their need of artificial gravity, and industrial storage spaces which are larger. The industry buildings or storage facilities themselves are built and pressurized if needed, and they fit within these spaces like "pills", to ensure modularity of everything. Transportation in this area is made by attachment to the beams. Vehicles transporting people or materials move on these beams like on "all-around" rails (more thoroughly described in section 3.2 – internal transportation). Construction and repairs or any other work needed to be done on the structure and the industry pills are made through the floating ArmDroids we designed (section 5.1). They move to the required site through the outside and then attach to the beams and do their job. People that supervise and coordinate industry operations, but do not need to be at the site, conduct this from the industrial office area in the central cylindrical unit.

The **layer of solar cells** provides some of the energy needed for the various operations required to sustain the settlement. The layers between the torus segments are sustained by a mesh of steel-nickel tubes, which also forms a **circumferential tube**, allowing a different way of moving from segment to segment.

The **specially shaped mirror** provides natural sunlight to the settlement's inhabitants by reflecting incoming solar light to the main level of the residential torus segments. The volume enveloped by the mirror surface serves industrial purposes, and is non-pressurized.

The outer walls of the torus segments must be light, resistant and insulating. Our team proposes as the main materials, used for the construction of the settlement, polymers and iron based materials. Nanobots are intermingled through the wall structure so that when an object hits the respective section, the nanobots rapidly fill with material the hole, thus avoiding air leeks.

Polymers such as polyethylene heavily impregnated with hydrogen are used for protection against high-energy protons, neutrons and alpha particles, ethylene tetrafluoroethylene for windows construction being much less massive than glass and transmitting more light. Layers of lead are used for stopping high energy gamma rays. A typical wall structure is shown in picture. The table below identifies the main volumes and surfaces:

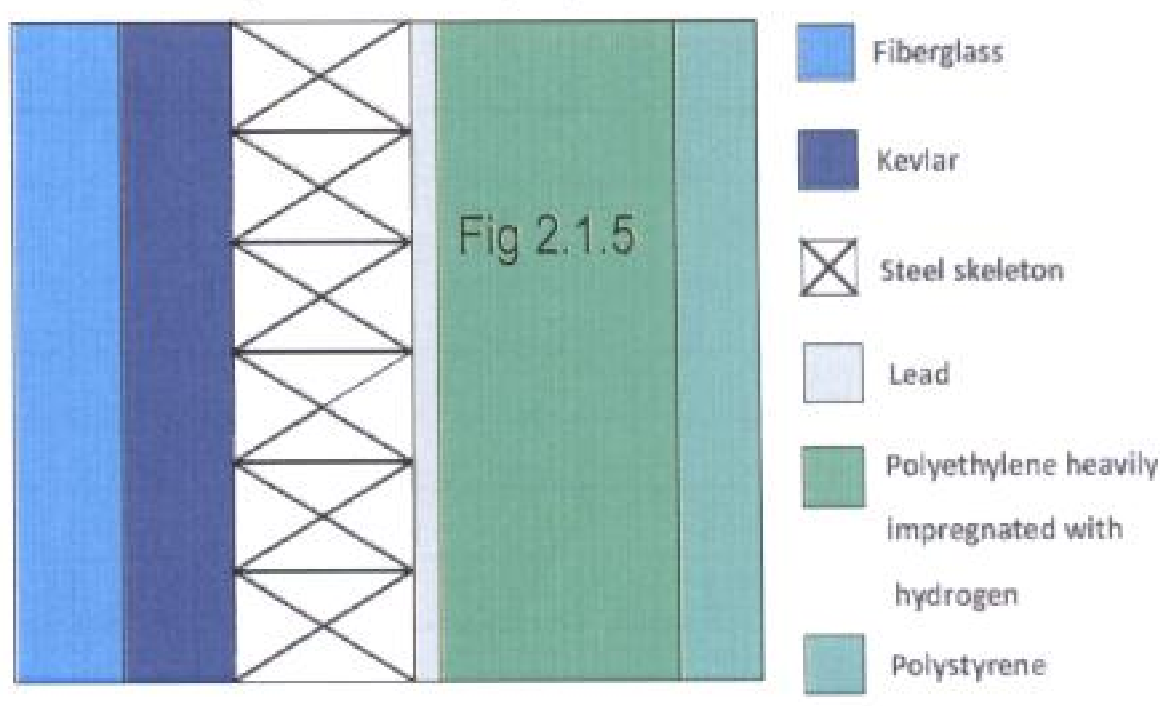


Fig 2.1.5

	Unit	Formula/Symbol	Value
	Number of people	N	19,000
	Large radius	R	3000 m
	Number of residential torus segments	n	3
	Number of sideways torus segments	$2n$	6
Residential Torus Segments (RTS)	Radius	r	200 m
	Habitable area radius	r_h	180 m
	Central angle	$\theta = \pi / 4$	45°
	Length	$L = R\theta$	2356 m
	Volume	$V = nR\theta(\pi r^2)$	888,191,075 m³
	Total surface	$A = nR\theta(2\pi r)$	8,878,140 m²
	Projected habitable area/level	$A_p = nR\theta(2r_h)$	2,543,400 m²
	Estimated area/resident	$A_1 = A_p / N$	134 m²
Sideways Torus Segments (STS)	Radius	r_S	230 m
	Central angle	$\theta_s = \pi / 20$	9°
	Length	$L_S = R\theta_s$	472 m

	Total surface	$A = 2nR\theta_s(2\pi r_s)$	**4,092,615 m²**
	Agricultural volume	$V = nR\theta_s(\pi r_s^2)$	**235,325,396 m³**
	Estimated agricultural area	A_{ag}	**5,903,096 m²**
	Docking volume	$V_d = nR\theta_s(\pi r_s^2)/2$	**117,662,698 m³**
	Recreational volume	$V_r = nR\theta_s(\pi r_s^2)/2$	**117,662,698 m³**
	Agricultural surface/resident	$A_{ag1} = A_{ag}/N$	**334 m²**
Central Industrial Zone (CIZ)	Mean Radius	R_{cm}	**1000 m**
	Mean Height	H_{cm}	**1500 m**
	Estimated Volume	V_{es}	**2,912,388,980 m³**
0g Outpost (0GO)	Radius	r_l	**200 m**
	Surface	$A_l = 4\pi r_l^2$	**502,660 m²**
	Volume	$V = \frac{4\pi r_l^3}{3}$	**33,510,325 m³**
Space ports A and B (SPA/SPB)	Radius	R_A	**450 m**
	Height	H_A	**150 m**
	Volume	$V_{spa} = \pi R_A^2 H_A$	**95,423,063 m³**
	Surface	$A = 2\pi R_A H_A$	**423,850 m²**
Central Space Port C (SPC)	Radius	R_{SC}	**600 m**
	Height	H_{SC}	**200 m**
	Volume	$V_{spa} = \pi R_{SC}^2 H_{sc}$	**226,194,675 m³**
	Surface	$A = 2\pi R_{SC} H_{SC}$	**753,985 m²**
Central Cylinder Unit (CCU)	Radius	R_C	**260 m**
	Height	H_C	**550 m**
	Volume	$V_{spa} = \pi R_C^2 H_c$	**116,804,415 m³**
Interconnecting parts	**Spokes(b,c)** Radius	R_{sp}	**25 m**
	Central tube(e) Radius	R_{ct}	**40 m**
	Circumferential tubes(d) Radius	R_{crt}	**15 m**
Mirror	Estimated Volume	V_m	**904,320,000 m³**
	Estimated Industrial docking volume	V_d	**153,800,390 m³**
	Width	l	**2000 m**
	Height	h	**576 m**

2.2 Internal arrangement

Bellevistat is composed of 3 torus sections, identical when it comes to sizes and space allocation. The 18000 permanent inhabitants, and the need to provide an environment as closest to Earth's as possible, are some of the reasons for the torus' small radius of 200 meters. Although the maximum surface is obtained when the ground level is placed at the radius' level, we decided to lower this level by 80 meters. The livable surface lost by this is of 87104 square meters but the remainder surface of 862296 square meters is more than enough, and by this lowering a good impression of open, large space is created, a benefic psychological effect for the people. The angle between the torus segments tangent and the ground level is therefore 120 degrees instead of 90(if the floor was at radius' level)

So the first floor is 80 meters under the radius level and is the residential level. The large Surface is dedicated to fulfill inhabitants' need to have gardens, to grow plants (limited within this section) as binding necessity with psychical comfort.

Under this there is a 10 meter level for plumbing which houses utility services such as water distribution, waste management, climate control, but also for the automatic transport system ensuring the transport of people and goods through the residential level and connectivity to the rest of the transportation system.

The next level is 20 meters high and it is destined for light industry, needed to supply decent human lifestyle, as well as clothing, water storage and recycling facilities, different appliances, etc. There are also special bunkers, one underneath each residential neighborhood with the purpose of safe keeping pregnant women, children and other sensitive people during solar flares.

Under this level there is another 10 meters plumbing level which provides the same services, but for the industrial area.

Each torus section has two robot maintenance areas which act as repair and small level assembly areas. Here the activity of robots and automations on the torus sections in general is being controlled. The first of these areas is pressurized and dedicated for automations and systems used in pressurized areas inside the torus sections, and is 20 meters high.

Under this level there is a 30 meters level called "Deposit" level. It is mainly a storage level, for goods needed by the inhabitants of the torus sections, for later use or for export. All access in this area is made by automatic means.

The last area to the outside is the second robot maintenance area, depressurized, with a thickness of 20 meters. This accounts for the maintenance of exterior automations and robots, of solar panels, robotic arms etc.

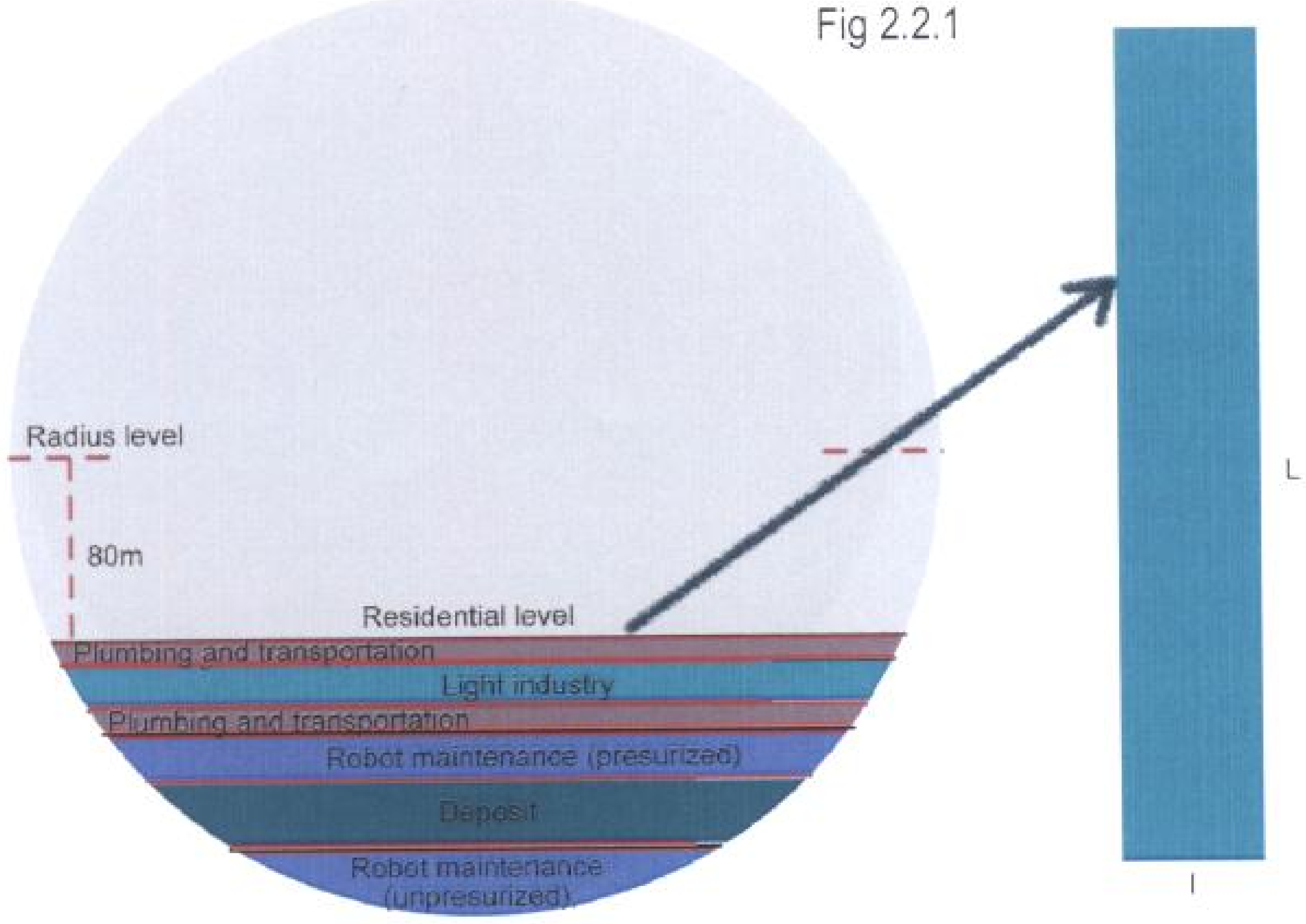


Fig 2.2.1

The theoretical remainder of 10 meters is incorporated in each floor's thickness and the torus' exterior wall.

	l (m)	L (m)	height (m)	Surface (m*m)	Aprox. Volume (m*m*m)
Residential area(surface)	366	2356		862296	
Light industry area	334	2356	20	786904	15738080
Robot maintenance (pressurized)	285	2356	20	671460	13429200
Deposit area	210	2356	30	494760	14842800
Robot maintenance (depressurized)	124	2356	20	292144	5842880

The two smaller radius sections at the side of each torus section are divided as follows: one contains the launching port at the side of the torus section in "vertical" cut (to the outside) and automated, industrialized agriculture to the torus section side, and the other section is used for agriculture exclusively. The first residential level of the torus section, as well as the first plumbing level continues on to these sections as well. The first level of the larger torus section used only for agriculture is used for combining usefulness with leisure and beauty, in order to simulate as much as possible, a pleasant and familiar ambient, similar to that on Earth, and the lower levels are dedicated to intense, industrialized agriculture, meant to satisfy all inhabitants' food production and adjacent necessities. These two sections are more thoroughly described and shown in sections 3.2.1 and 3.4.

The central cylindrical unit is composed of two large transport stations at the vertical ends, which are the main connection points for all transport, and the vertical space between them (stations) which is used for 0g utilities. Thus, we have a 0g hospital used for special need cases and research purposes, 0g fire department and intervention unit and the central office area, where people that work in the central industrial zone go. Also there is the main water tank, for Bellevistat's water management

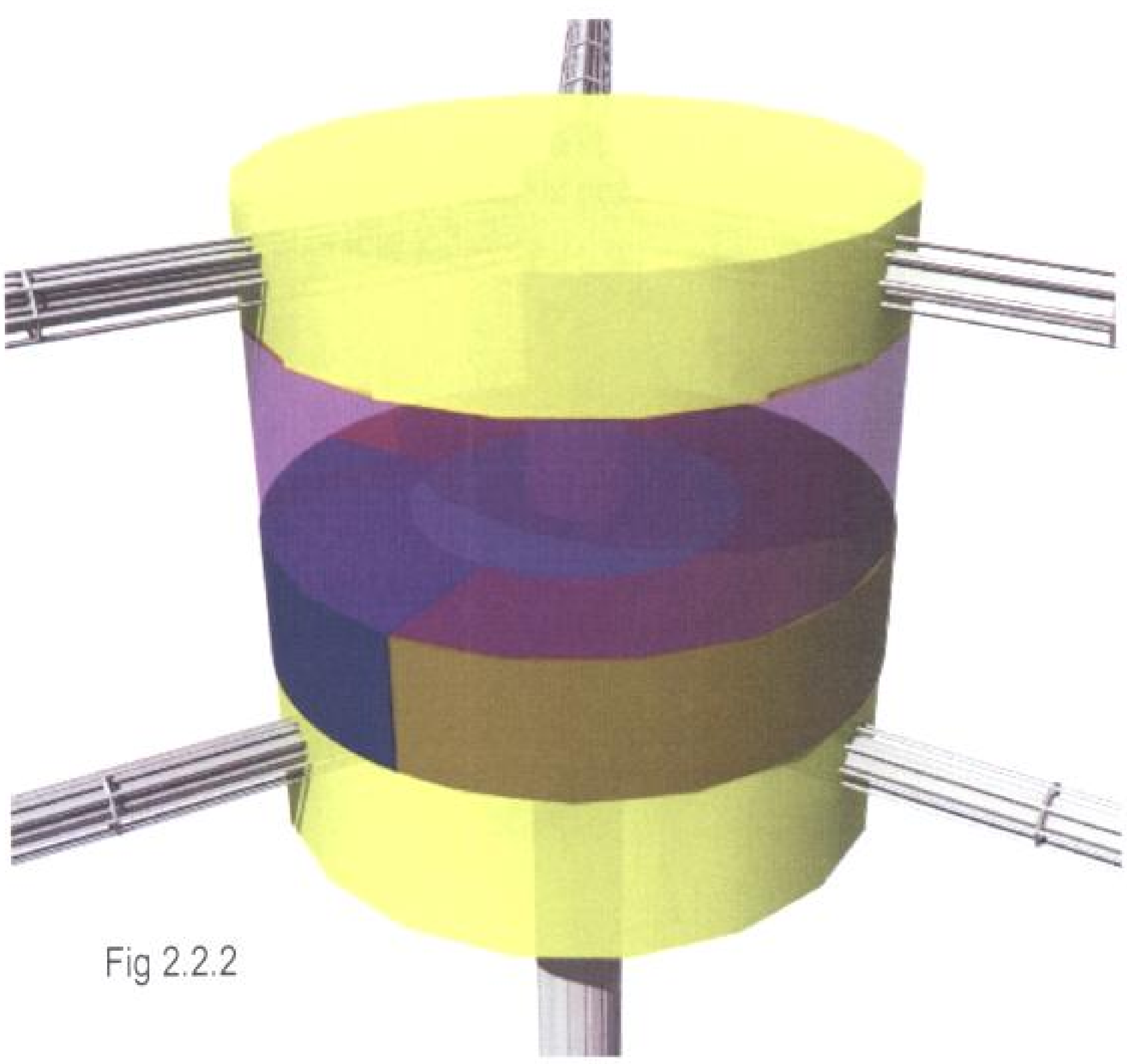


Fig 2.2.2

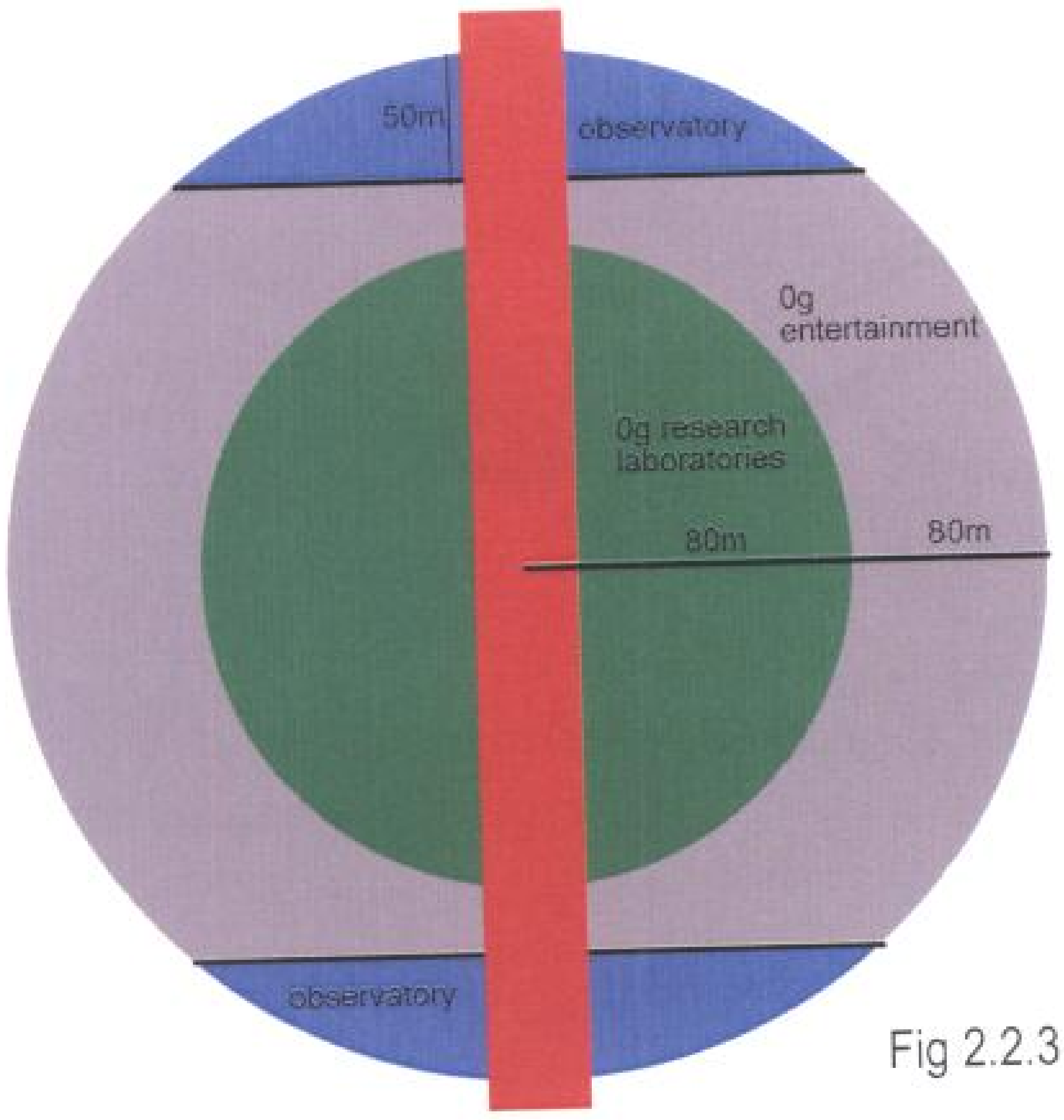


Fig 2.2.3

system, and assembly space for industrial robots.

Between the central industrial zone and the central mirror, on the central tube, there is the 0g Outpost. The upper and lower ends of it have a rotation movement opposite to the station's, of the same angular velocity, serve as observation outposts for research or touristic purposes. The rest of the Outpost is dedicated to research laboratories of different types (physics, chemistry, biology, etc.) and 0g entertainment (see section 4.5).

At the lower end of the central tube there is the central mirror. This ensures the day/night cycle, and the back side has a construction site, a docking and launching port for ships. The construction function of the back of the mirror is described in section 7-manufacturing.

2.3 Construction sequence

The space settlement's construction will be anticipated by the construction of a mining and processing operation on the asteroid found in L4. Then a pre-assembled module arrives from Alexandriat to L4 where the station is going to be built, assembled and launched. This consists of a fragment of the central vertical tube, the central cylinder around it and a part of space port C (as shown in Fig 2.3.1), and will represent the starting point for Bellevistat's construction.

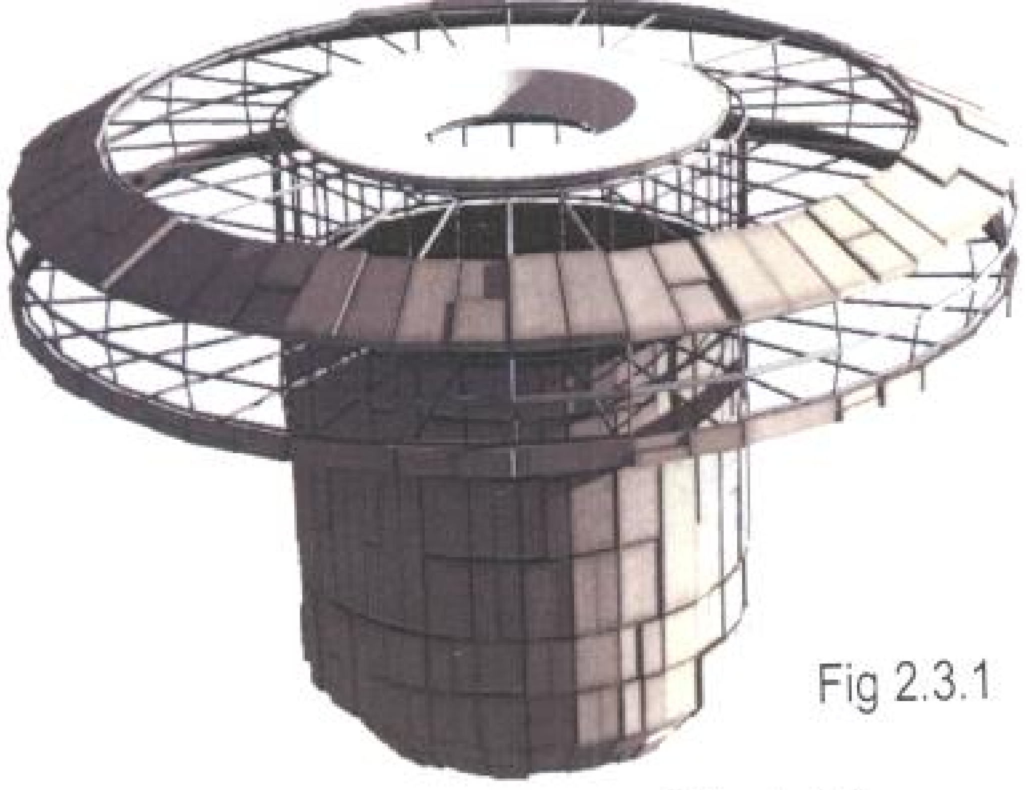


Fig 2.3.1

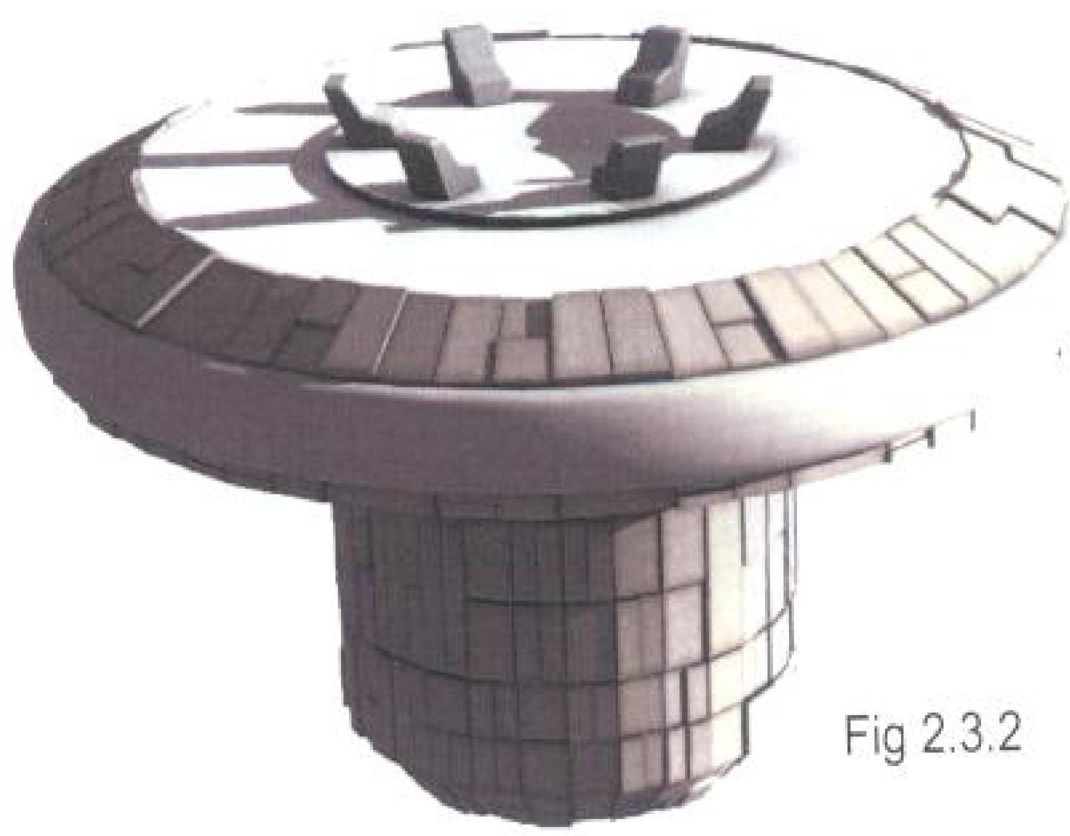


Fig 2.3.2

The second sequence of the building process consists of finishing space port C and the assembly of the necessary robots. In sequence 3 these robots will start building the six spokes that lead to where the torus segments will be built (Fig 2.3.2).

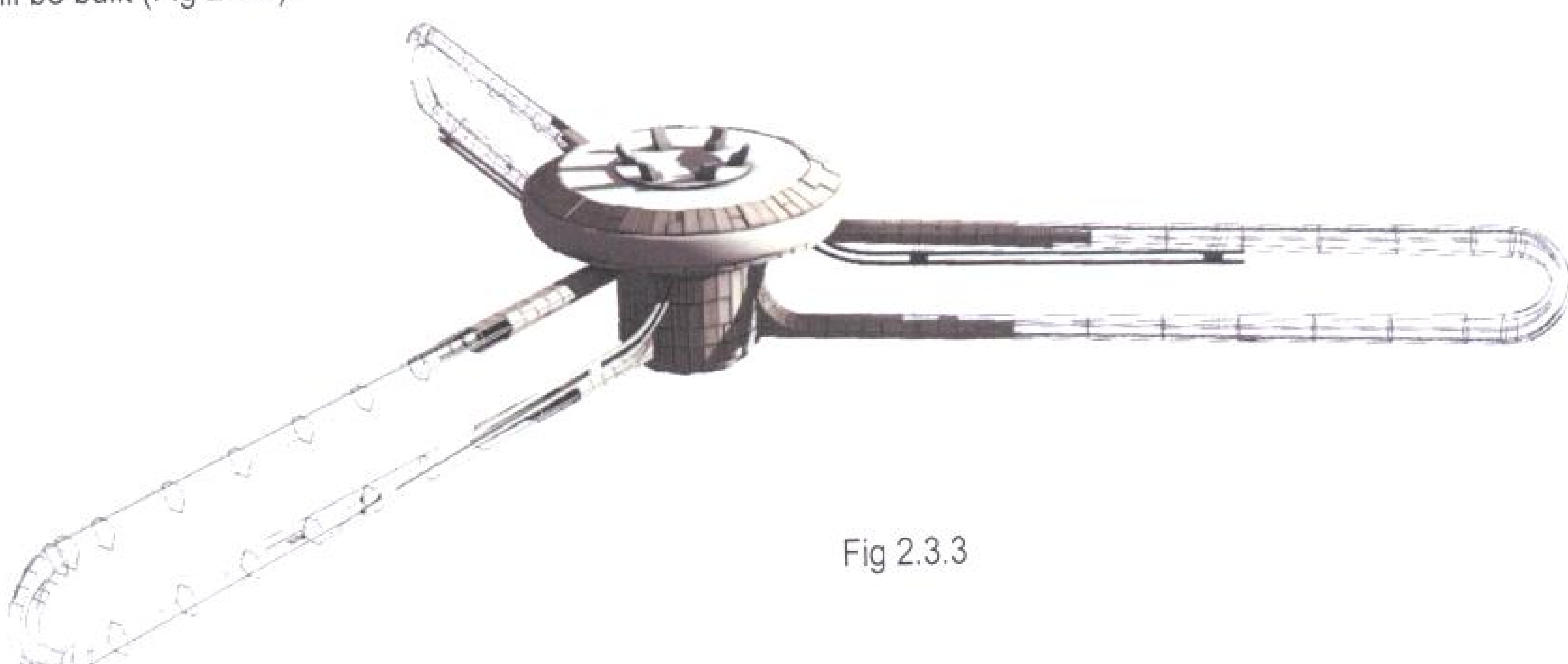


Fig 2.3.3

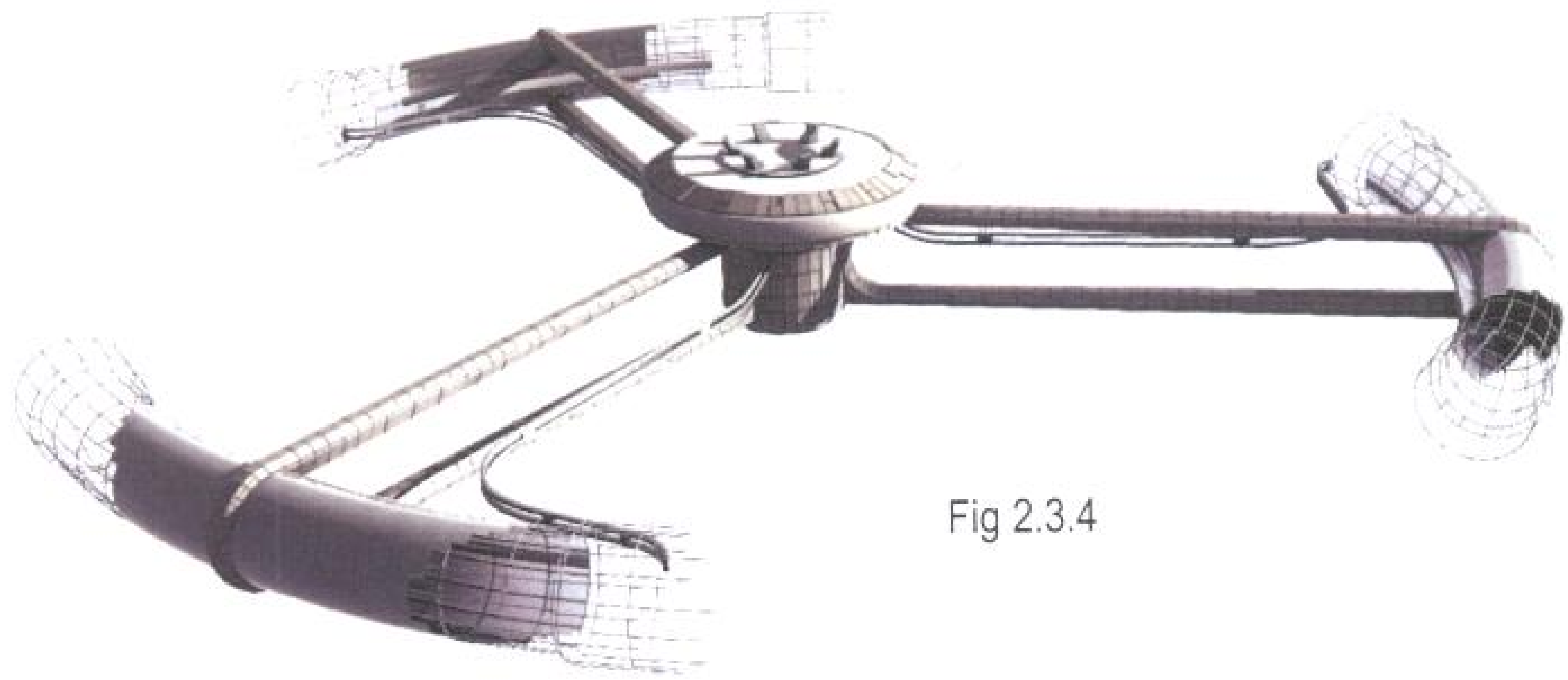


Fig 2.3.4

In Sequence 4 the torus segments are built along with the thicker segments at their edges, and along with the station's engines.

Sequence 5 consists of building the lateral arms, the outer circular connection tubes and the central tube towards the mirror (along with the framework for the central industrial zone), and in sequence 6 we build the upper two docking ports, the lower mirror and construction site on the back of it, along with all the necessary finishing (Outpost) and the solar panel skirt

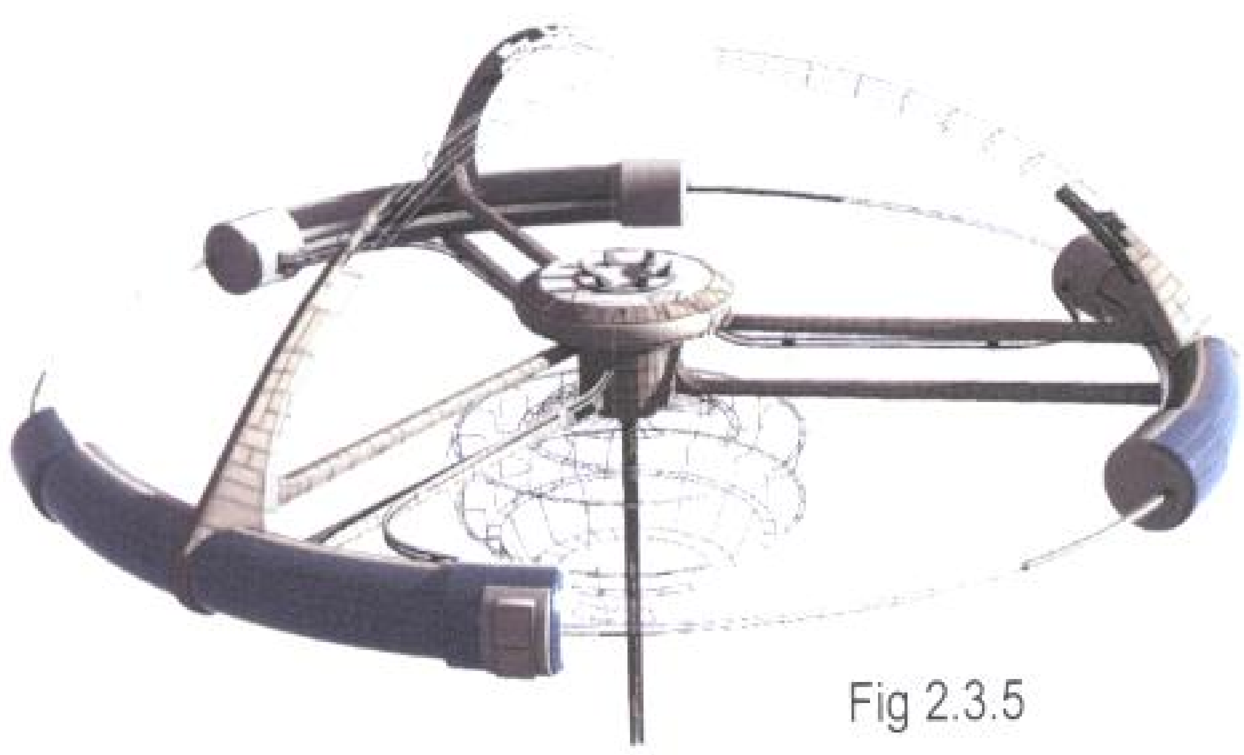


Fig 2.3.5

(Fig 2.3.5 and Fig 2.3.6). This is the point when we will inflict the station's rotation movement, gradually. It is the perfect timing as it has enough structural resistance to hold together, and as the interior finishing of the torus segment is about to begin (building houses and finishing their interiors requires gravity).

All along this process, material is supplied continuously from the ferro-nickel asteroid and is supervised by people.

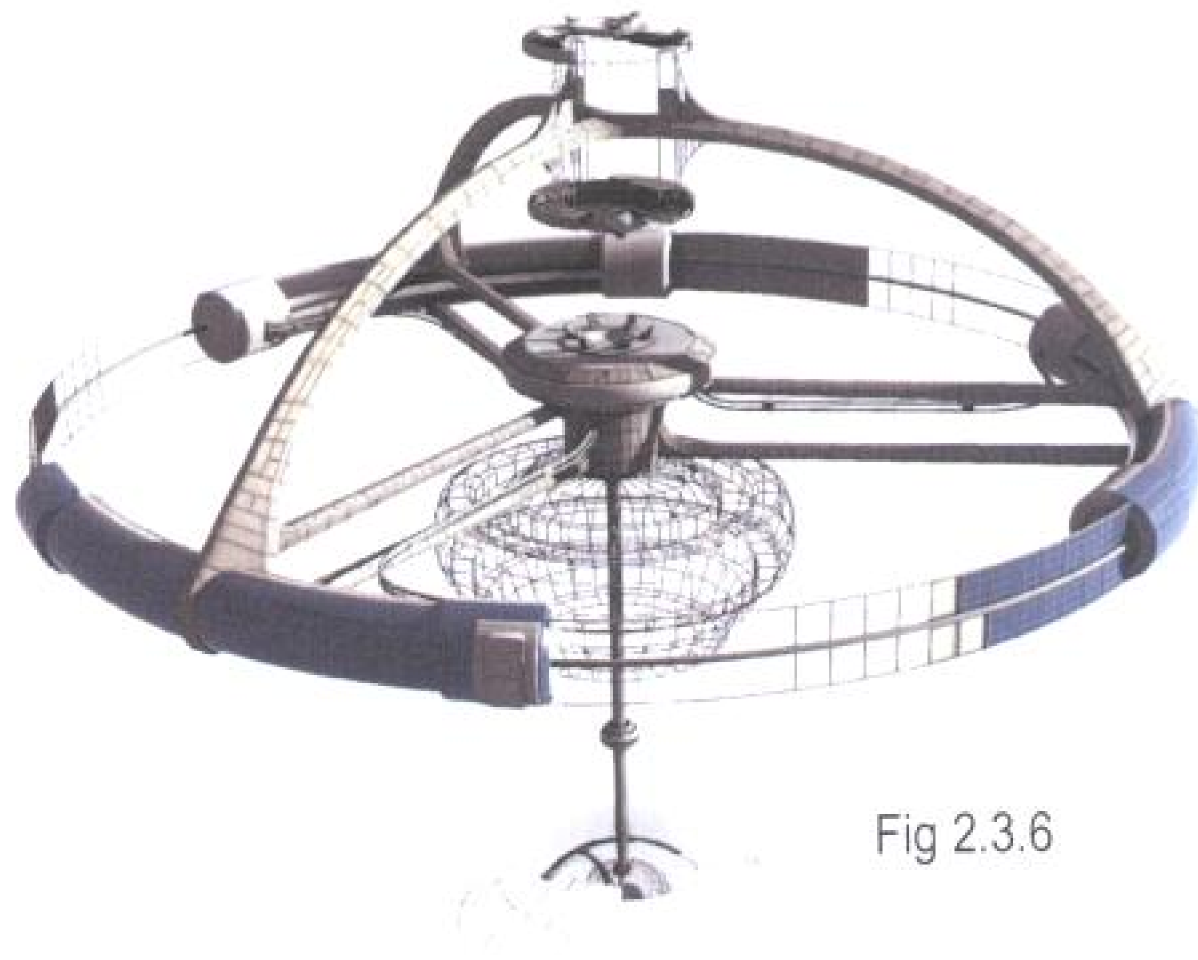


Fig 2.3.6

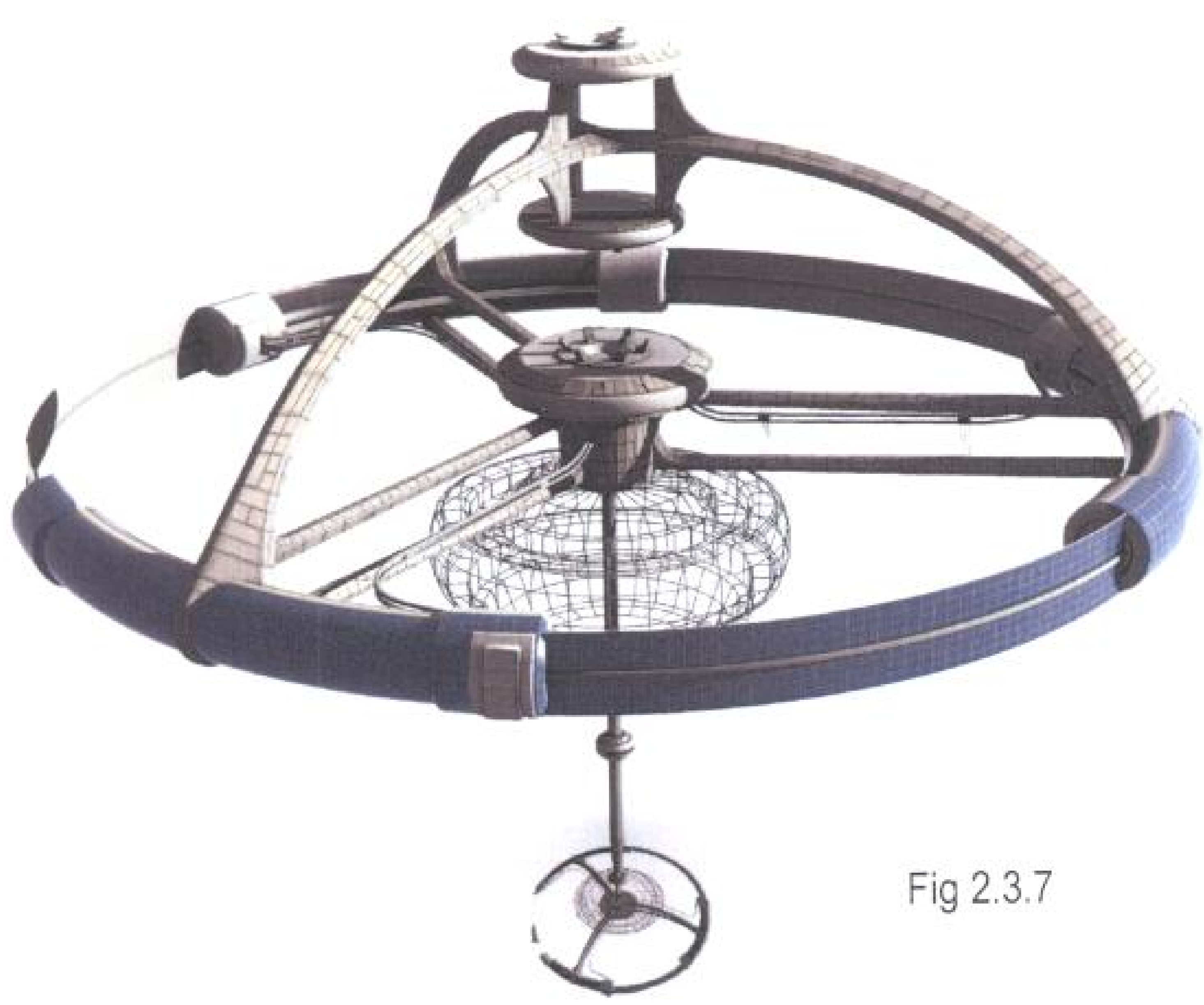


Fig 2.3.7

2.4 Mining Facility

Any captured asteroid brought near Bellevistat for exploitation is put on a circular orbit around L4 (similar to Bellevistat's but further, circling the potential pot), orbit situated at approximately 100 km from our station's orbit (see Fig 2.4.1), and all mining and primary refining operations are done at that site. We do not bring raw ores on our station but only refined materials, so that we can minimize the dust and foreign materials intrusion to the station. Estimating the asteroid density at approximately 6000 kg/m^3, considering that it has a radius of 500 m, and using the formula below, we found that the gravitational force the asteroid exerts on the settlement reaches only 2000N (M = mass of asteroid, m = mass of settlement, d = distance between, k = universal gravitational constant), a force small enough to be periodically counter-balanced by thrusters.

$$\vec{F} = \frac{kMm}{r^3} \cdot \vec{r}$$

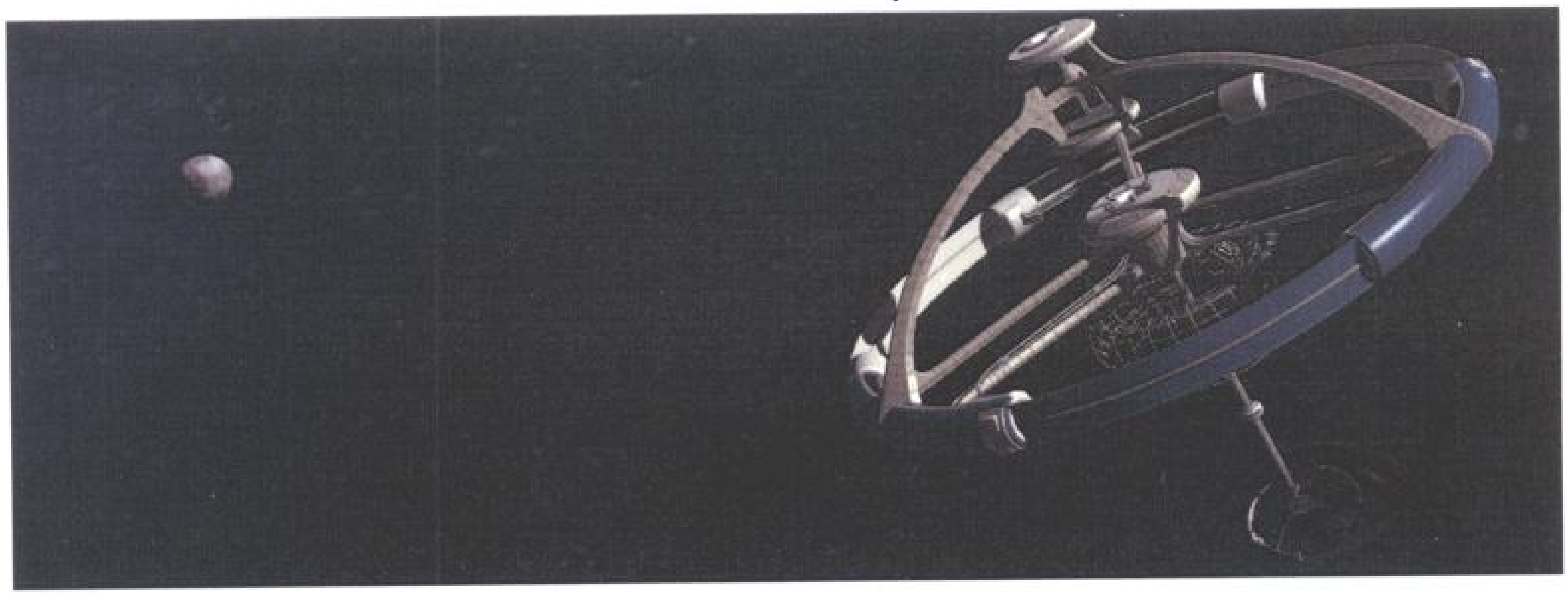


Fig 2.4.1

Once the asteroid is secured on an orbit, a modular standard mining operation is deployed. This develops as follows:

Firstly, transport ships are sent to the asteroid, which transport the mining processing unit (factory), people's headquarters and robots. All these except the robots are sent in pieces and are assembled on the spot by the robots - spiderBuilders (see section 5.1). Because the gravity on asteroids is neglectable, all structures built are "anchored" firmly into the ground.

Once these modular facilities have been assembled, the robots begin building "utility warehouses" at best location sites on the asteroid, around the "factory". They build these structures by using the super ADOBE technique. A resistance framework is built from steel, meant to keep the building together and give it shape, and then the walls are filled in by using this technique. Bags are filled with asteroid soil and put into the structure. Its final form is that of an igloo, with four openings laterally disposed, through which robots can operate (unload, refuel, etc.). These structures are also anchored into the ground.

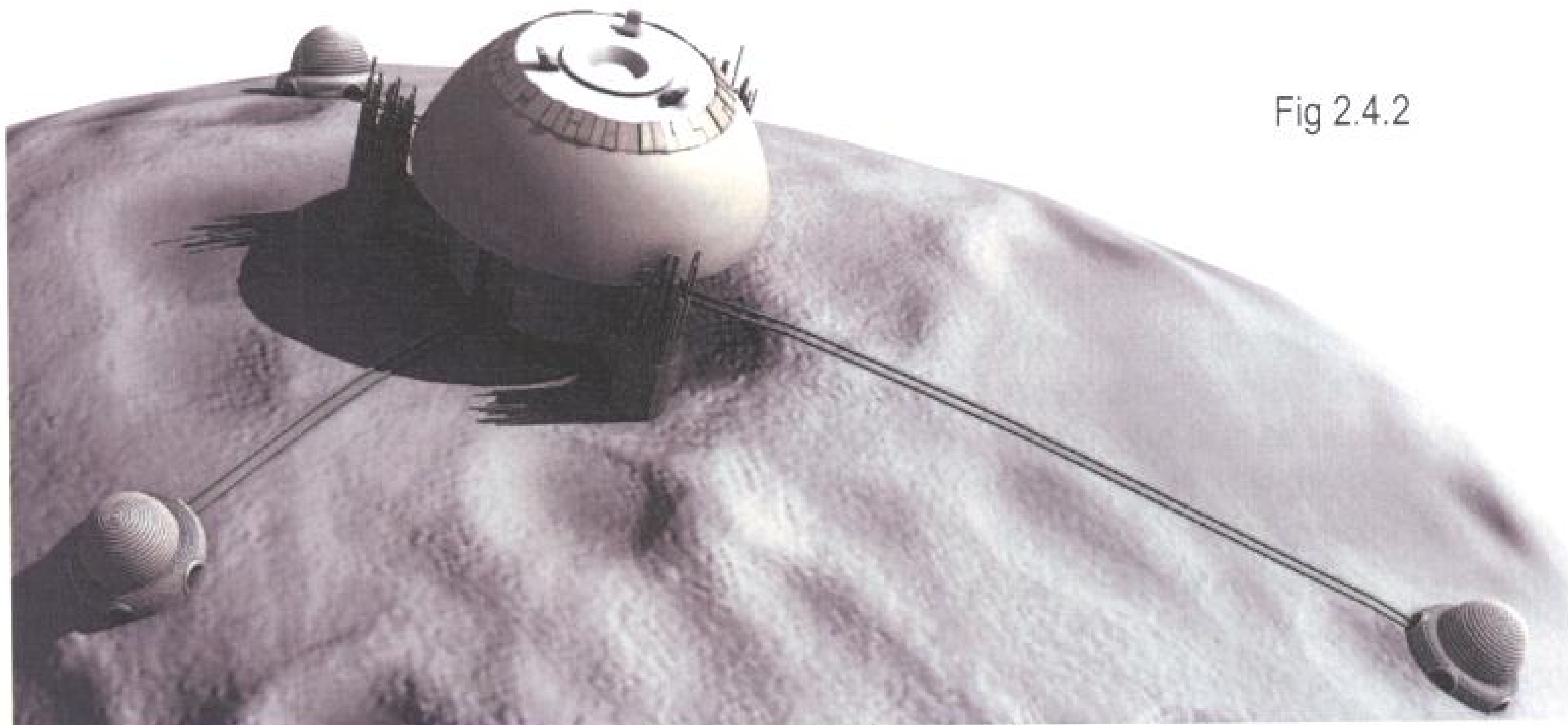


Fig 2.4.2

The igloos are connected with the factory through a set of two rail-like bars. These bars act as support for electrical vehicles. These vehicles are very similarş to the ones used for transportation through the central industrial area, only these are electrically powered. They are the means for all igloo-factory traffic, and do that by attaching to these bars.

The process of mining goes as follows: Robots (Harvesters) mine raw ore from the asteroid surface around the igloo they are allocated to (mainly 2-3-4 robots per igloo depending on size). For mining details see section 5.5. These robots stack ore in their own tanks and when they fill up; they go and unload the ore into the igloo (warehouse). Ore is then transported through the "vehicles" to the factory where it is properly refined. The factory is designed with a special site above, where ships transporting refined materials to Bellevistat can connect and load / unload goods from the factory's own built-in warehouse. These ships then take the goods to our station where they are either exported or further used in the manufacturing process.

For the whole operation, hand –full of people are needed. Three people are needed to supervise the refining process, and then one additional one for each igloo and its robots, and finally a technician, that is responsible for the whole process, the whole road of the ore, from extracting to uploading on an incoming ship, making sure no cuts are made on the way. This means that a typical mining operation needs an estimate of 7 to 10 people working on site, depending on its size (volume of extraction).

The factory and people's quarters are situated at a safe distance from the igloos so that dust problems are minimized. In case a robot should need repairs it is brought by a transporting ship (fastTranspShip) to the factory (which also has a repair depot) and the technician takes care of it.

The electrical power for each of this operation is supplied by a solar power satellite, which transmits the energy in the form of microwaves. This satellite is placed close to the mining operation. But far enough so that it is not affected by dust or other debris.

When it is decided that the mining operation has served its purpose, all structures and robots are re-packed and transported away. The only structures left behind are the igloos, as they are mainly made of asteroid, useless material. This is a typical mining operation and can be deployed on other space bodies as well. If the space body is massive enough to have its own strong gravity field (such as the Moon or other planets and moons), the structures do not need to be anchored.

2.5 Docking facilities

For redundancy and safety purposes Bellevistat provides four different and widely separated docking sites. There are also 3 smaller ports at the end of each torus segment, and on the lateral „arms" which launch small ships, so these take advantage of the settlement's rotation speed and therefore reducing launch fuel consumption.

Because of the ship's rotation around its central axis, a place in close proximity of this axis is most recommended for docking. Thus, all the docking sites are placed on this axis, and separated vertically. They are independent, in case one should be damaged, the rest of them can proportionally take its functions. Under normal conditions, in order to minimize traffic they are thought as follows: the two top ones are for docking of ships transporting people and people's goods; the middle one, above the industry is for heavier traffic necessities as it provides close access to the industry zone and the torus segments through the central station; finally the one on the back of the mirror is for larger ships, industry purposed mainly. This one also serves as release point for newly built ships or components, as it is not connected to the launching release ports.

2.5.1 Central docking ports – Procedure

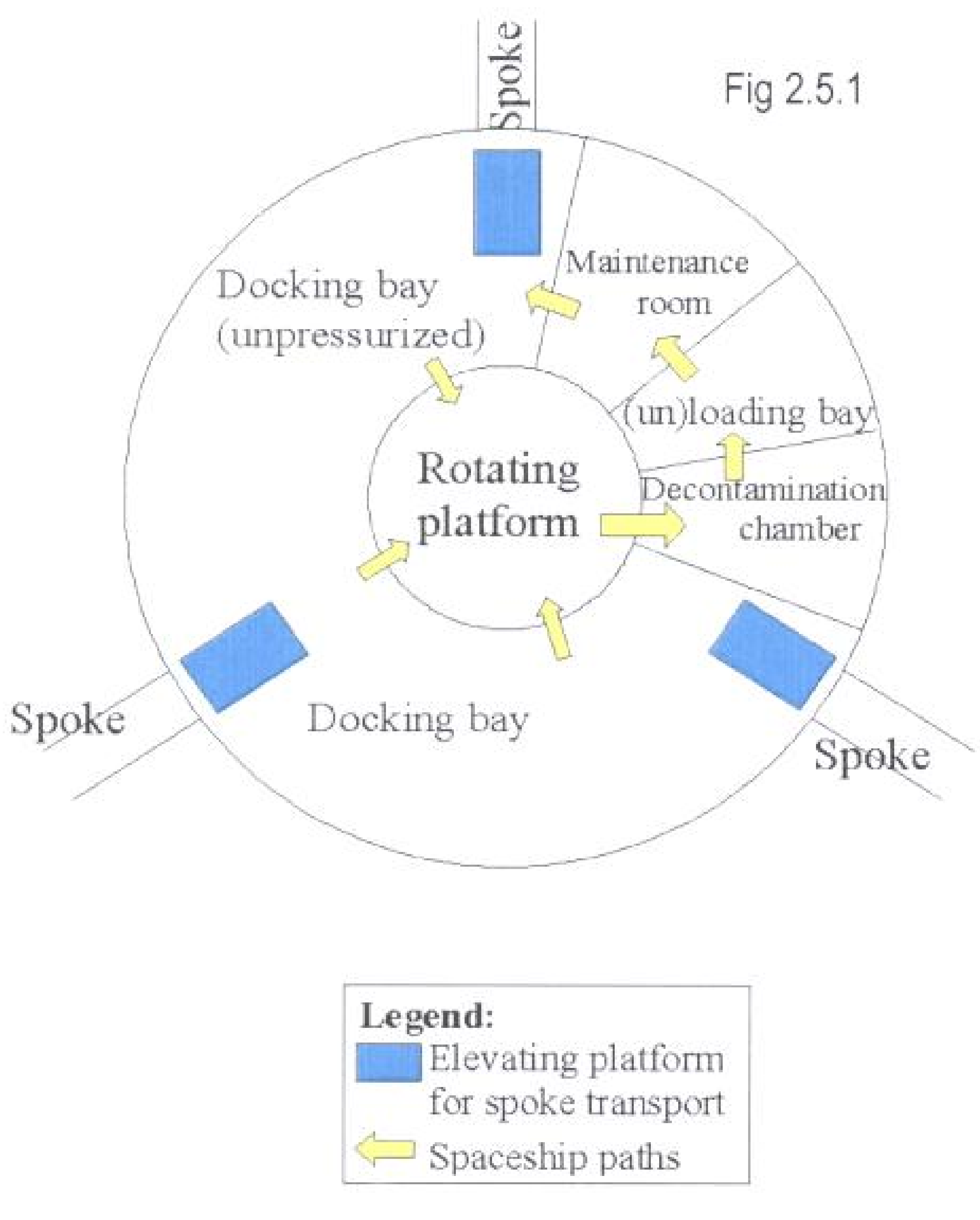


Fig 2.5.1

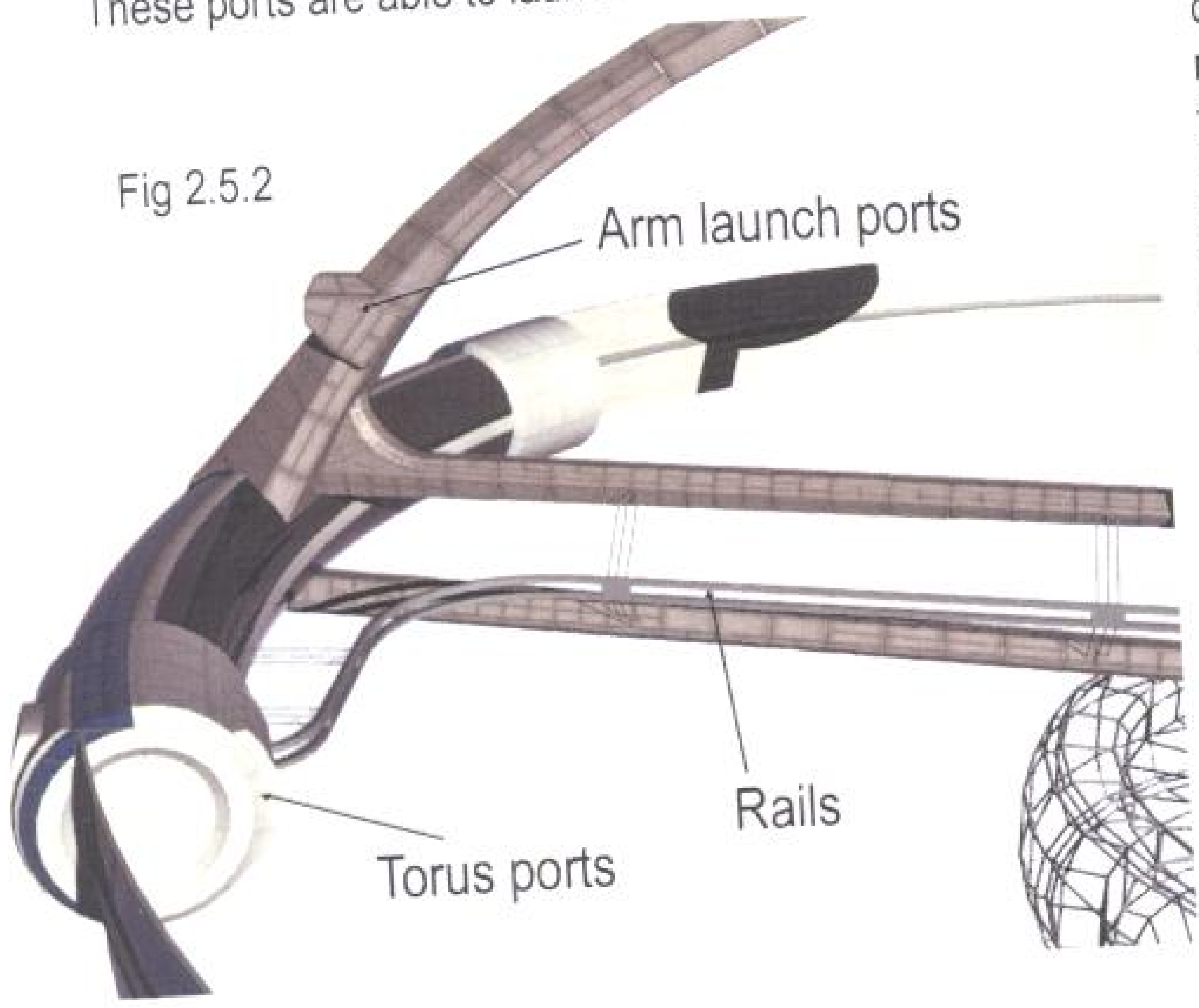
The four large docking sites, as shown in Fig. 2.5.1, are mainly for incoming ships, and the departure of very large cargo or human ships. The procedure for docking is as follows: The incoming ship approaches on the middle axis where there is minimum rotation. The ship lowers and attaches to the middle platform of the port. This platform rotates in an opposite direction from the station, thus being practically still compared to the incoming ship, and making the docking as smooth as possible. Then the platform is smoothly stopped from its rotation and the ship is lowered a level and passes through the decontamination room, unloading and uploading (people and goods), maintenance room (where it is attended to should it need repairs or other works), and finally is parked in the docking bay if it needs to be on Bellevistat for a longer period of time. When a ship needs to be taken to the rails leading to the torus ports it is put on the "elevating platform" and lowered to the level of the rails(whether it's the ones in the middle or the ones within the lateral arms) and then follows its course.

There is a second docking bay, at the same level as the landing platform, because spaceships have their own protection against small debris and radiation, so there is no need to place it in an enclosed, pressurized space.

2.5.2 Torus spaceports

These ports are able to launch small shuttles transporting people or goods, exploring shuttles, satellites or any other destination shuttles with a relatively small mass and can not affect the rotation movement of the station too much, using the settlement's peripherical rotation speed of 177 m/s (at the outer edge). When a ship is due to depart, it goes from the central docking bay, or the upper two ones to the exterior spaceports via the set of rails in figure 2.5.2 or the ones at the interior of the lateral arms. When it reaches the port, it can stop and load people or cargo. Then it waits for the right moment (desired tangential trajectory) and leaves the station.

Fig 2.5.2



3.0 Operations and infrastructure

3.1 Construction Materials Sources

Gravity is the main force that governs the motion of all space objects. In the theory of general relativity, Einstein visualized the motion of objects in gravitational fields as that of an object on the surface of Earth moving from valleys to hill tops. The more massive the body, the deeper the "valley" it creates around itself. But in a two body system also form "shallow" valleys. There are five interesting points in a two body system. They are called Lagrange points, and they are points where the gravitational forces of the two bodies acting on a third much smaller object would make it rotate at the frequency the two bodies rotate around the center of mass, thus keeping the same distance from the two bodies. Of the five points, three are rather unstable and require orbit corrections. The others however, are remarkably stable, so that an object rotating around them would follow the same path forever (in not threatened by an asteroid or comet or other space objects). In the figure below, the Lagrange points of the Earth-Moon system are shown.

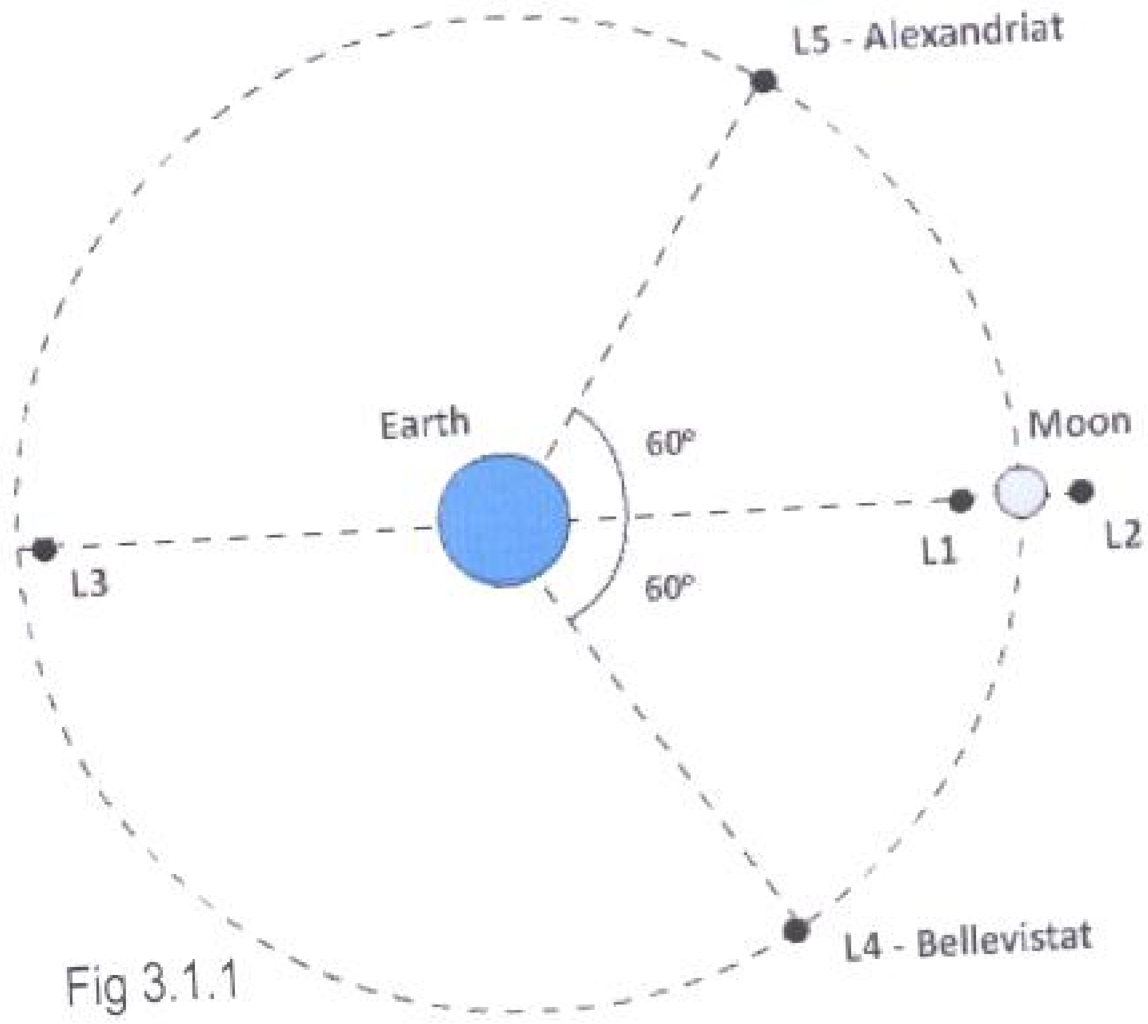


Fig 3.1.1

Source	Material/Equipment	Purpose	Transport Mean	Storage
Earth	N_2 (nitrogen)	Atmosphere	Percherons + Space Tugs	Torus
	Kevlar	Wall component	Percherons + Space Tugs	-
	Pb (lead)	Radiation protection	Percherons + Space Tugs	-
	Construction Robots	Settlement construction		
Moon	FeTiO3; (Na,Ca)Al2Si2O8; (Fe,Mg)SiO4; (Ca,Fe,Mg)Si2O6; SiO2; Fe2O3; Ar; NH3	Obtaining: H2O O2; H2; Fe; TiO2; Al; Si; N2;	Cargo ship (Moon model)	Central Zone Storage Area

Alexandriat	Mining facility	Asteroid mining (fabrication of steel – nickel alloy beams and plates)	-	-
	Ferro-nickel asteroid	Fe; Ni; silicates	Foundation Society	L4 (orbit)
	Bellevistat Central Unit	Settlement construction	Foundation Society	-
Asteroids	Eros 433 - S type	Silicates	Cargo ship (Asteroid Model)	Central Zone Storage Area
	(6178) 1986 DA - M type	Fe;Ni;		
	Mathilde – C type	carbonaceous compounds		

Bellevistat is placed in Lagrange point L4, where it will be built with the materials mined from the ferro-nickel asteroid by the facility provided by the Foundation Society. This location offers easy access to lunar resources, and in the mean-time the settlement is kept close to Earth, with which profitable commercial trade will be developed and which can be a source of rare materials, not found elsewhere. The settlement is oriented (Fig 3.1.2, not drawn to scale) so that its rotation axis is always perpendicular on the plane of motion, as to ensure the conservation of the spin kinetic momentum.

Fig 3.1.2

The materials for the construction and operation of Bellevistat are transported from a variety of sources. Materials from the Moon or from other asteroids are more likely to be exploited, since both the Moon and the asteroids have a shallow gravity well, which means it is cheaper to extract materials from them. Materials from Earth are imported as a last resort, if there is no other mean of obtaining them from elsewhere. Alexandriat also provides some of the primary components and equipment for building Bellevistat, and transport of an additional ferro-nickel asteroid plus a mining facility giving the settlement construction a kick-start.

For mining natural satellites, our company collaborates with "Explotronic, Co. Ltd" that works on another project named SELENA (Small Ecologic Lunar Excavator with Network Activity) that provides automated systems, robots and other structures capable of obtaining different materials.

3.2.1 Food production and distribution

The life of the plants is as important as the life of the people that inhabit Bellevistat, because it produces O_2 and nourishment from simple compounds such as CO_2, H_2O. To maintain the balance of life on the settlement, plants are essential if they receive optimal conditions. The most important factors that influence their growth are the nutrients (minerals, C, H, N_2, O_2, P, S), the soil and the climatic conditions (temperature, light, atmospheric composition) so that the processes of photosynthesis, circulation and respiration are more efficient.

The natural soil forms in millions of years and the costs to import it from Earth are huge, so we concluded that we use an artificial soil on Bellevistat formed of two major types of nutrients: macronutrients (C, H, O, N, P, S, K and Ca) and micronutrients (C, Fe, Mn, B, Zn, Cu, and Ni) obtained through the asteroid mining. Some substances resulted from the household waste, from intense filtration of water, can be used to obtain fertilizers. These are put in tanks, near the waste management area of the residential segment of torus, together with organic garbage from the agricultural area and asteroid soil, that it's cheaper than lunar soil (regolith). In this way, by creating conditions that are optimal for the development of decomposing bacteria and worms, the nutrients improve the soil with organic substances that have a smaller molecule, resulting in more aired, fertile soil improved according to the necessities of the settlement.

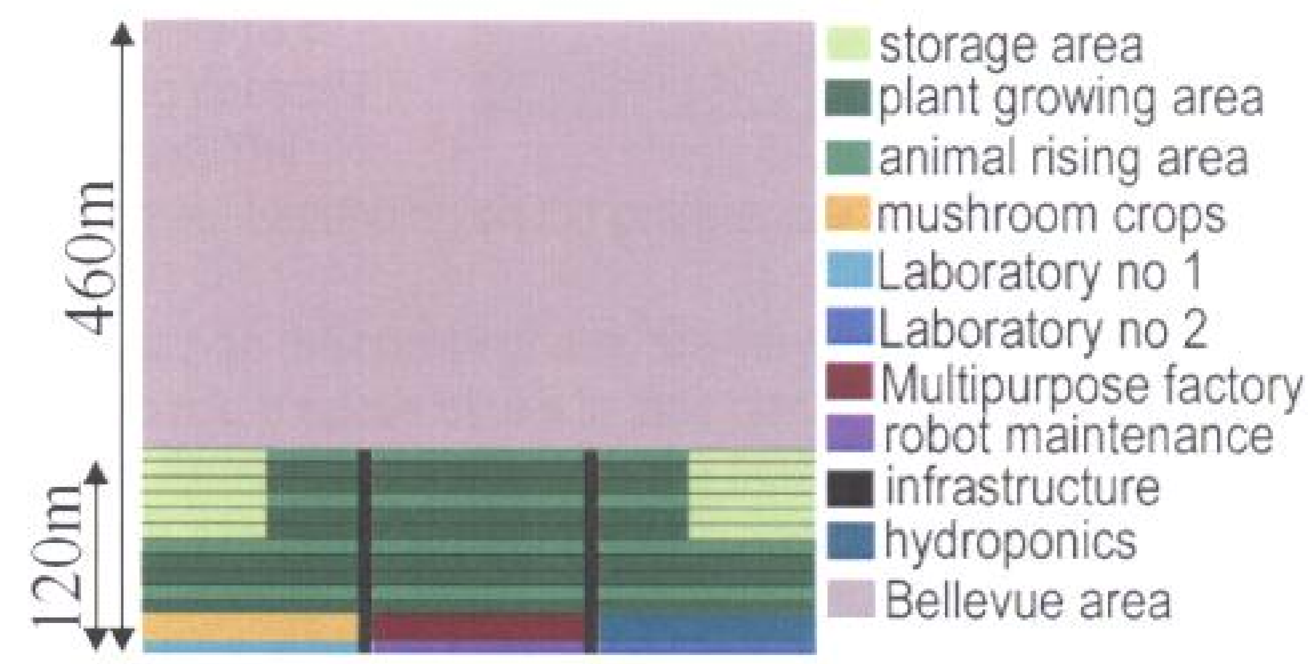


Fig 3.2.1.2

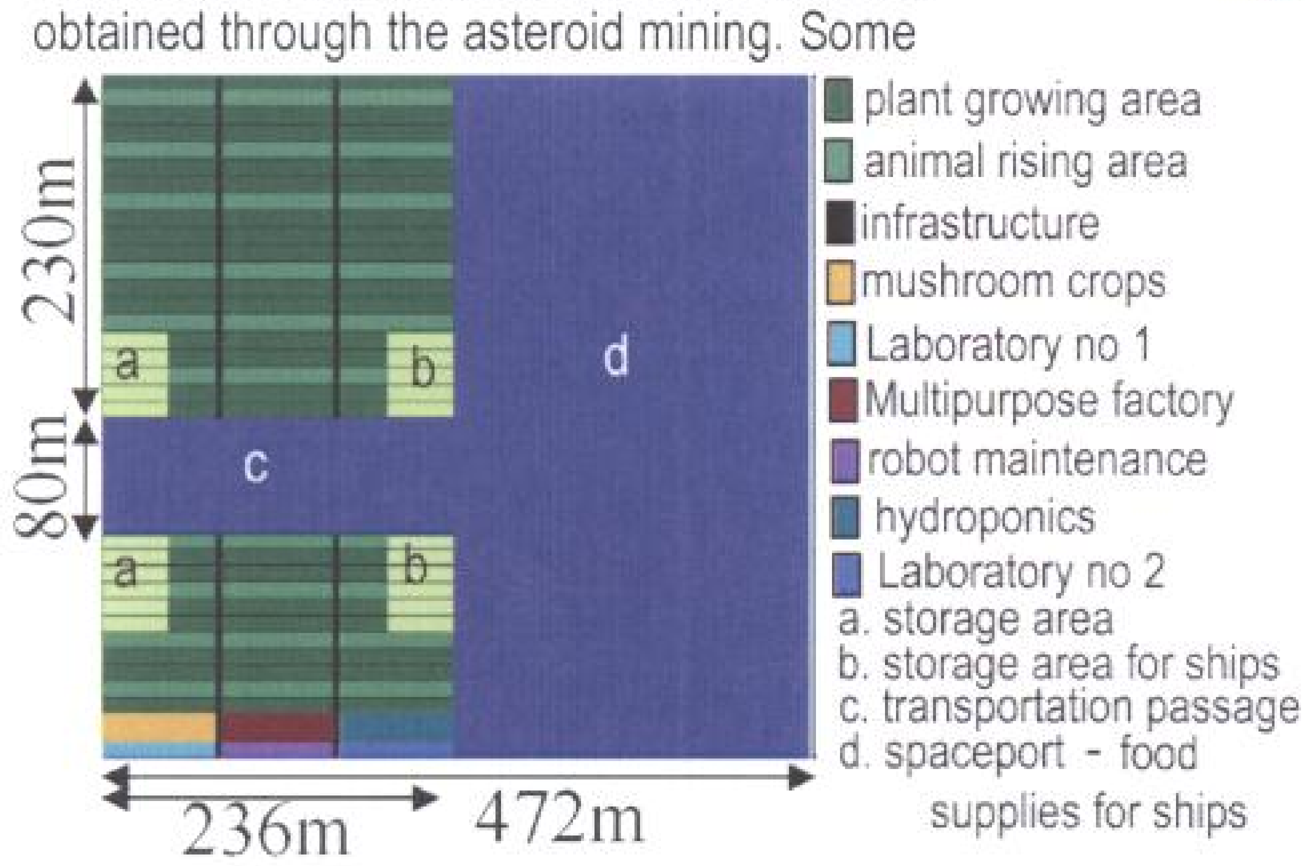


Fig 3.2.1.1

Humidity and temperature are permanently controlled by the automatic acclimatization system that responds to plants' necessities.

We tried not to raise species of plants or animals that are genetically modified, because we wanted to avoid the eventual diseases, dysfunction of the human body, caused by the unlimited consumption term. Even so, in each of the 6 agricultural areas we have two research laboratories: Laboratory no 1, where inhabitants try to obtain new species of plants or animals that occupy less volume and are more productive (ex. Small species of trees like apple tree that reach maximum 5 meters high to avoid accidents) and Laboratory no 2, where plants, animals, food products are daily checked if they are healthy, to avoid the apparition of an epidemic danger. The difference between the two Sideways Torus Segments consists of the number of floors where plants are grown and animals raised (11,6m between floors). The Bellevue Sideway torus segment has 11 floors, 7 of them designed for plant growing and the rest to the raise of animals (Fig 3.2.1.2), while the intense plant growth sideway torus (spaceport + agricultural) has a total of 31 floors (10 for animals; 21 for plants) disposed alternatively (Fig 3.2.1.1). Bellevistat disposes of 5,903,096 m^2 for the food production, approximately 334 m^2 for each resident, with the possibility of adding more floors any time it is needed a bigger quantity of food (for exports, trade). The system used is the crop rotation, combined with the robots and automatic pipes that decide the daily necessary amount of water and minerals for every type of plant in order to grow productive and healthy. The same is with the animals feeding too, performed through robots that decide the daily necessary of vitamins, water and minerals. Another type of crops are mushrooms and the hydroponics that don't need any crop rotation. The transport between the floors is made through the infrastructure system, that has 5 m wide and it contains lifts (transportation for food, feed to the Multipurpose factory, Laboratories, storage areas etc.), water and acclimatization pipes etc.

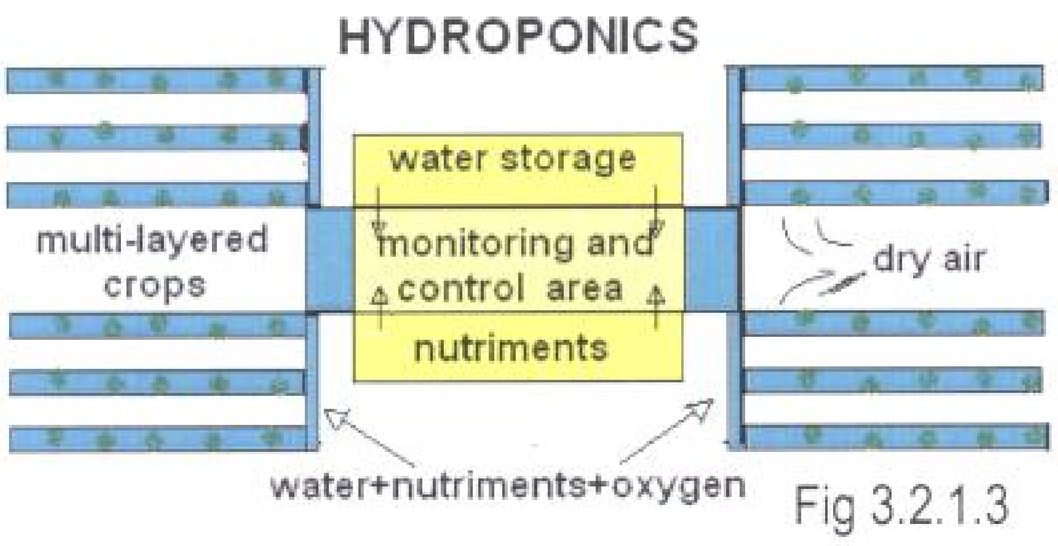
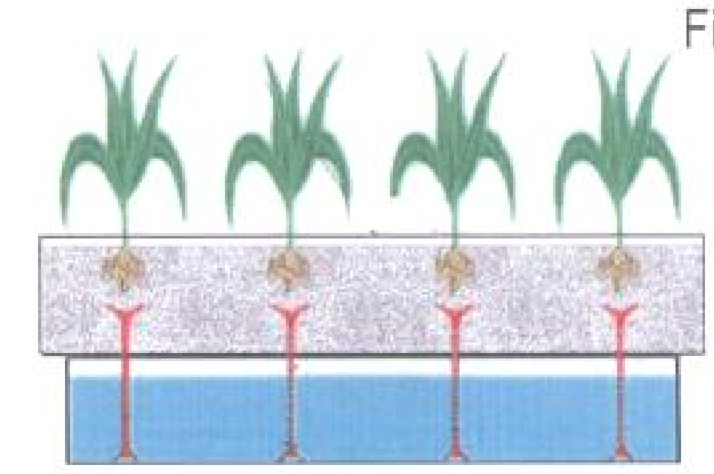


Fig 3.2.1.3

The term hydroponics (Fig 3.2.1.3 and Fig 3.2.1.4) refers to growing plants in the absence of soil, its supporting and nourishing functions being replaced by a system of pipes, similar to an irrigation system. The pipelines in which the roots of plants are fixed contain water with soluble nutriments (e.g. N, P etc.) and oxygen. The technology utilizes the capacity of plants to absorb mineral nutriments after a preliminary dissolving in water, which diminishes the actual role of soil in feeding the plants. The water storage may contain a part of the sewage (e.g. washing water) from the residential area (after a preliminary filtration), and the nutriments used must be compatible with the mineral necessities of all plants (especially vegetables).

Fig 3.2.1.4



Since the light spectrum used the most by plants during photosynthesis is red, or blue the illumination of the plantations utilizes this specific spectrum.

Crops to be grown:

Taking into consideration the basic nutritional requirements of the future residents, the general consumption of a human being does not exceed 60-70% of the total production capacity of the settlement. The rest of the space available is to be cultivated with additional crops, depending on the preferences of the population or for economic reasons (e.g. sales to other space settlements).

We considered that NASA's studies from 1975, regarding the choice of diet, are very important when choosing the Bellevistat's menu, but we decided to eliminate some products and propose others in their place. We proposed sheep and goats, because we can benefit from their milk, wool and meat. Another inconvenient is the trout, a pretentious fish that requires permanently filtered water, cooled and running. That is why we proposed the carp and the tilapia that breed and reproduce rapidly and don't require running waters.

As for the quail, we took them into consideration because they are economical and their eggs don't have counter indications. Instead of the sugar plantations that would require pollination we breed bees **in enclosed areas** in order to use their honey as sweetener, while the propolis is used as preservative. We also studied the response of the human body to different medicinal plants like the white underbrush (Hypophae Rhammnoides), which has an essential role in ensuring the daily necessary doses of minerals and vitamins. It is also rich in vitamin C (4000-8000 mg/100 g juice), A, B1, B3, B6, B9, E, K, P, celluloses, beta-carotene, phosphorous. Being such a complex product almost the same with ginseng, each resident is administered 10 g of underbrush per day. Another special plant that we have chosen for our residents' health is the green barley (hordeum vulgare). When it reaches 20-30 cm high, it contains the best nutritive resources for the human cell, decelerating the aging process. Comparing it to other plants the green barley contains 250 times more vitamin A than the salad, 25 times more potassium than the bananas, 11 times more calcium than the milk, 11 times more iron than the celery, 7 times more vitamin C than the oranges, 10 times more vitamin B1than the spinach etc., therefore, to the residents is offered 250 grames of green barley juice daily. We also needed algae like Spirulina that is incredibly rich containing a balance of nutrients that make it virtually a 'whole food' capable of sustaining life without the need for other food and other species. Algae have photosynthetic machinery and so produce oxygen. Another proposal of ours is to cultivate the Water

Hyacinth (Eichhornia crassipes), as it filtrates water, it loves polluted waters and can be used to produce furniture Another proposal of ours is to cultivate the Water Hyacinth as it filtrates water, it loves polluted waters and can be used to produce furniture. For the clothing industry we proposed the cotton plant (Gossypium hirsutum) and the flax (linum usitatissimum).

Food available on the settlement from Nasa studies and our studies					
Source	Amount	Cal's	Carbohydrates	fats	proteins
	g	kcal	g	g	g
Tilapia (fish)	100	128	0	2.65	I26.15
Carp	100	162	0	7.17	22.86
Rabbit	40	64	0	3.2	8.4
Sheep	100	234	0.08	11.09	33.43
Goat	100	143	0	3.03	27.10
Chicken	40	49	0	1.3	8.8
Ornit quail (coturnix coturnix)	100	234	0	14.10	25.10
Duck (Cairina Moschata)	140	182	0	15.7	32,9
produce					
Chicken eggs	24	39	0.2	2.8	3.1
Ornit quail eggs	9	14	0.04	1	1.17
Duck eggs	70	129	1	10	9
Sheep milk	100	108	5.32	7	5.98
Goat milk	100	69	4.45	4.14	3.56

Table of plants cultivated on the station

Category	Name		Energy Value (Kcal)	Protein(G)	Carbo-Hydrate(G)	Fat(G)
	ENGLISH	LATIN	per 100 g			
Cereals	Wheat	Triticum	338	13.50	72.28	2
	Maze	Zea mays	89	3	18	1.10
	Barley	Hordeum vulgare	354	12.48	73.48	2.30
	Oats	Avena sativa	389	16.89	66.27	6.90
	Soybean	Glycine max	30	3.04	5.94	0.18
	Rice	Oryza sativa	130	2.38	28.59	0.21
	Rye	Secale cereale	335	14.76	69.76	2.50
	Sunflower	Helianthus annuus	570	32	18.75	1
Vegetables & Spices	Tomato	Solanum lycopersicum	20	1	4	0.20
	Cucumber	Cucumis sativus	20	0.65	3.63	0.11
	Pepper	Capsicum annuum	20	0.86	4.64	0.17
	Cabbage	Brassica oleracea	20	1.4	0.10	5.60
	Lettuce	Lactuca sativa	10	1.4	2.2	0.20
	Carrots	Daucus carota	40	1	9	0.20
	Potato	Solanum tuberosum	80	2	19	0.10
	Beans	Phaselous vulgaris	330	24	60	1
	Pea	Pisum sativum	80	5.40	14.50	0.40
	Cauliflower	Brassica oleracea	20	2	5	0
	Mushroom	Agaricus bisporus	35	5	2.30	0.50
	Spinach	Spinacia oleracea	25	3.50	2	0.30
	Nettle	Urtica dioica	68	7.90	7.11	0.70
	Onion	Allium cepa	40	1.40	8	0.20
	Garlic	Allium sativum	137	7.20	26	0.20
	Dill	Anethum graveolens				
	Parsley	Petroselinum sativum				
	Savory	Satureia hortensis				

	Laurel	Laurel nobilis				
	Orange tree					
	Lemon tree	Citrus limon				
	Apple tree	Pyrus Malus				
	Cotton plant	Gossypium hirsutum				
	Watermelon	Citrullus lanatus				
	Hazelnut tree	Corylus avellana				
	Pistachio tree	Pistacia vera				
	Cactus - Prickly Pears	Cactaceae Opuntieae -> Opuntia ficus - indica, fruits: prickly pears				
	Cactus - Hylocereus	Cactaceae Hylocereus - their fruits are known as pitaya or dragonfruits				
	Grape-Vine	Vitis Vinifera				
	Coffee	Coffea canephora				
	Cocoa tree	Theobroma cacao				
Medicinal Plants	English Name Latin Name	Latin Name		English Name		
	1.White underbrush	Subter ramale	6.Lavender	Lavandula		
	2.Hawthorn	Crataegus monogyna	7.Camomile	Matricaria chamomilla		
	3.Aloe	Aloe arborescens	8.Dog Rose	Rosa Canina - high vitamin C level, used for: tea,syrup,marmelade		
	4Bilberry bush	Vaccinium myrtillus				
	5.Dandelion	Asteraceae Taraxacum				

Processing and stocking

Harvesting and storing of food products is done by the agricultural robots or by the automatic systems from each floor, both supervised by the human residents. After the checking imposed by Laboratory no.2, the food is collected, packed and sent to the multipurpose factory from each agricultural area. Here taking in consideration their purpose, they are packed, vacuumed sealed, pasteurized (milk pasteurization), boiled and sent in different areas of the factory for example: some cereals and vegetables (wheat, corn, soybeans etc.) need a drying operation; a convection oven for processing the animal products for the immediate consumption (milk pasteurization, boiling, roasting and warming of the meat in order to inactivate the dangerous enzymes). For the same reason, before being stored in aseptic, recyclable (to prevent tainting) packages, the products are treated with ultraviolet waves, and/or with propolis as a preservative. The storage is done in depressurized warehouses, 4 available in each of the the intense plant growth sideway torus (agriculture -space port), 2 of them serve for the food alimentation of the space vehicles, and the other 2 for storage between crops and in case of the production is stopped because of an epidemic or a disease. We can find the last 2 in the Bellevue Sideway torus segments too.

To obtain an efficient distribution system we use special pipes in which the the packages are sent to programmed destinations. Some of the products are stored and others are sent to the residential area for immediate consumption. The selling of products is done automatically in the settlement. The food is sent to both private and public customers (groceries, restaurants etc), after a previous request (in general with 1-2 days before) and it can be: fresh (directly from the agricultural area: fish, eggs, milk, fruits, vegetables etc), recently processed or conserved (from the multipurpose factory most sorts of food and rough-wrought products). Special deliveries (eventually at home) are also possible, along with sales to other space settlements. The payment is done with cards, in „spatial credits" that have their equivalent on Earth in $.

3.2.2 Electrical power generation and distribution

The generation and distribution of electrical power is one of the most crucial tasks the settlement has to fulfill in order to properly sustain all its internal and external operations. The close proximity to the Sun makes the solar energy the most space environmentally friendly, cheap, efficient way of generating electrical power, by photovoltaic cells.

These cells cover the exterior part of the torus segments, and the gap between them, so that during the rotation motion the projected area of the layer of cells is constant at any time, implying that the power output of the station is held constant. The projected area is equivalent with the projected area of the outer surface of a cylinder with radius $R = 3000m$ and height $h = 2r = 400m$.

The basic principle on which these photovoltaic cells work is the following one: photons "move" tightly bound electrons from the valence band into the conduction band, where they can "flow" freely through the material, thus generating electric current. But as quantum mechanics successfully predicts, only photons which have the band-gap energy are able to excite atoms to higher energy levels, the rest of them contributing to thermal motion, by interacting through other effects, thus to the increase in temperature. To ensure the maximum efficiency of the photovoltaic cells, multiple layers with different band-gap energies are used, so a wider portion of the solar spectrum can be put to good use and also an antireflective coating covers the layers of cells so as to absorb as much photons as possible.

Due to these facts, the efficiency of the cells is rather low. The technology is still in progress and the current breakthroughs have made photovoltaic cells efficiency reach new levels. The efficiency of the cells that will power the settlement is assumed to be 35%.

For the calculation of the power generated, an amount of 1340 W/m^2 of power is supposed to pass through each square meter of cell projected area. In the table below, the main properties of the photovoltaic cell layer are quantified.

Unit	Value
Cell layer area	$A_c = 10{,}000{,}000\ m^2$
Cell layer projected area	$A_{pc} = 2{,}400{,}000\ m^2$
Solar radiation intensity	$E = 1340\ W/m^2$
Cell's efficiency	$\eta = 0.35$
Power output	$P = 1{,}125{,}600{,}000\ W$

$$\Phi = \int \vec{E}d\vec{s} = \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} Eds\cos\theta$$

$$\Phi = \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} hRd\theta\cos\theta\,\Phi = \int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} hRd\theta\cos\theta$$

$$\Phi = 2rR\int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} d\theta\cos\theta\, d\theta = 4rR$$

$$P = E\eta\Phi$$

Use	Power
Residential	39 MW
Space ports A and B	50 MW (each)
Central Space Port C(and station)	75 MW
Central Zone industry	500 MW
Mirror industry	250 MW
Research Labs	10 MW

Studies performed have shown that non-industrial space communities require a power output of 10 MW for 5,000 people. This means that for Bellevistat, which is designed to accommodate a maximum of 19,500 residents, the power requirement for strict non-industrial activities is 39 MW. As Bellevistat is meant to be the primary space manufacturing center in Earth's orbit, a much higher power output is required. Our team anticipates that the power generated by Bellevistat's photovoltaic cell layers suffices the power necessary for its industrial activities. The table shows the allocation of electrical power.

Another "fleet" of 50 solar power satellites are placed into orbit around the Sun, near Earth's orbit further enhancing the power generated. Each of these satellites exposes an area of 70x100m, the entire fleet generating about 164MW. The power can be easily transmitted either to Bellevistat or to Earth by microwaves.

An efficient power storage system is also required, because Bellevistat is eclipsed once every 28 days by the Earth, and excess power can easily be transmitted through microwaves on Earth, being a mean of sustaining its economy. A very efficient way of storing electrical energy that takes advantage of the space background radiation (temperature of 2.7 K, which is a temperature in the range of the superconducting domain of most metals) is the superconducting magnetic energy system. These systems store energy in the magnetic field generated by a superconducting coil. They are highly efficient systems reaching efficiencies as high as 95%. The super-capacitors store energy in their electric field. They have capacities over 1,000 farads which are enormously high compared to ordinary capacitors which have capacities of the order of microfarads. Because of their high capacity, super-capacitors charge up very quickly.

The power is distributed through polymer-insulated wires made of copper. Copper is chosen because of its high conductivity. Power is the product of current and voltage, so to transmit a given power the two can be varied. If high intensity is used, there would be some serious power loss, because Joule effect, which states that the power over a conductor is transformed into heat. The power over a conductor is equal to the intensity squared times its resistance. But instead if high-voltage is used this automatically means low intensity currents. By keeping, where possible, the wires at the cosmic background temperature (which is in the range of superconductivity), their resistance is also very small, so the power loss is negligible. Also AC (alternate current) is mostly used because it is easier to transform from low to high voltages, and vice-versa, than DC (direct current). DC current is used for powering internal transport systems, and other system that require it.

3.2.3 Internal and external communication system

Bellevistat uses a wireless access point network for internal communications. Each access point on the settlement matters and can communicate with 25 clients at a time, each client located in a 100 meters radius. It's not a viable option to use wireless connection in an environment with lots of metals that could block the signal. This is why wireless access points are used only to collect clients' requests from one of the 3 torus segments or from the central zone and then send them through fiber optics cable to the central zone where the servers are stored. Most of the robots, the computers and even some appliances connect to the network to communicate with other robots, to get information from the server or to update the servers' information.

Bellevistat has an antenna placed in the mirror which is used for external communications. The antenna is similar to the antenna used for communications with Moon. It uses low frequency waves since they attenuate slower meaning they are better for long distance. The antenna has a frequency of 144 Hz and a radius of 75meters.This way people on the station can communicate with spaceships, people on earth or people on other settlements.

3.2.4 Internal transport systems

Transportation between the major components of the settlement is done through transportation tubes placed inside the resistance tubes that link them. Inside these tubes, there are railways, in both ways.

Inside horizontal tubes b1, b2, b3 and c1, c2, c3, we can find straight railways, where electricity-powered single wagon trains operate. These trains have special mobile chairs, that can change orientation in the plane determined by the three torus segments, in such a way that people inside are sustained against the resultant force from the three basic pseudo-forces that act at a given position, at a given velocity and acceleration. These forces are the centrifugal force (parallel with the tube), the Corriolis force (perpendicular on the tube) and the force of inertia, caused by the acceleration of the train. For trains that travel from the center of the settlement to the exterior, the train first accelerates in order to live the 0G zone. When the pseudo-gravitational force (centrifugal force) increases, the train begins opposing its natural trend to accelerate at a faster rate, in order to maintain an approximately constant velocity, as it moves further from the central zone. As it approaches the torus segments, the opposing force increases at a faster rate, in order to make the train decelerate, arriving at the torus station with zero velocity. Trains that travel from the exterior to the center will generate a traction force that will decrease from the exterior to the interior. Tubes b1, b2, b3 meet together in the center cylinder unit, through the station beneath the central port C, and tubes c1, c2, c3 also meet in the center cylinder unit through another station. The former station is associated more with transportation of people and materials in link with the space port, while the latter is associated with transportation of people and materials for the industrial zone and the industrial mirror.

Inside central tube e, there is another transportation tube with 0G trains for vertical transportation (relative to the torus plane). This tube will link the two central stations, the port, and on the other side the 0G outpost and the industrial mirror.

For tubes a1, a2, a3 that link the exterior torus segments with the Space Ports A and B, trains always move in the direction of the tube. However, the train acts through friction and traction in such a way that it generates a constant vertical component of the velocity (vertical means parallel with the central tube of the station). Consequently, vertical acceleration appears only in the vicinity of the torus segment. The chairs inside the train will move in a horizontal plane in a way similar to the chairs inside the trains traveling through tubes b1, b2, b3 and c1, c2, c3, only that they will have another movement possibility in the vertical plane determined by the tube trajectory. Because there is no vertical acceleration, the chair vertical rotation will be less complex, because the chair only needs to maintain its constant direction relative to the horizontal plane (moving relative to the train).

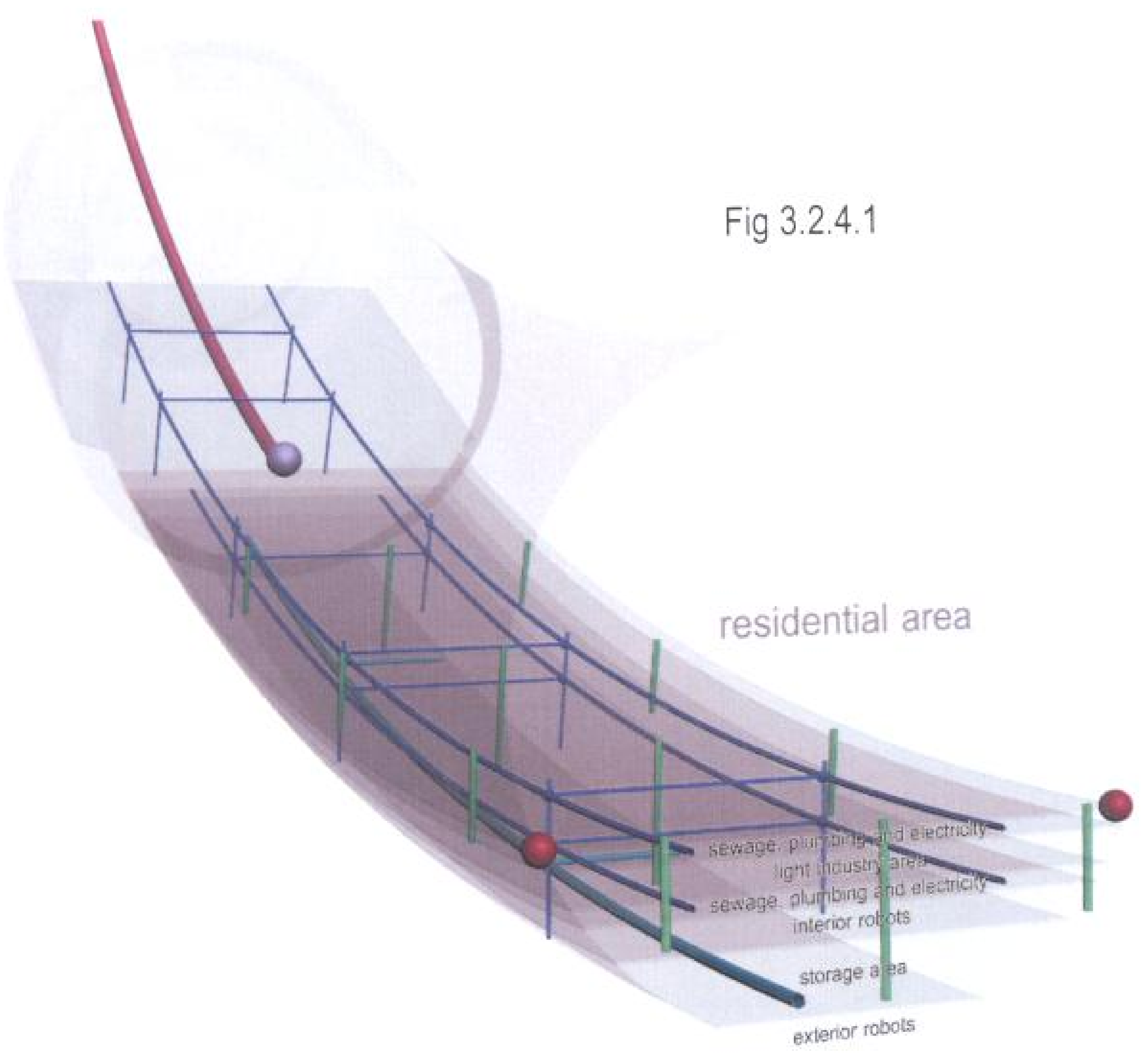


Fig 3.2.4.1

Circular tubes d1, d2, d3 also have railways inside, in order to ensure communication between every two torus segments. These tubes pass through the small torus segments, being isolated from the exterior Space Ports and the agricultural space inside them.

These railways end after the entrance in the main torus segments with one station (in the plumbing and transportation area under the residential area).

Inside each main torus segments there will be a system of trains and elevators for transportation of humans and materials. Four horizontal tubes will be placed inside the two transportation and plumbing areas, two in each. Vertical tubes for elevators will intersect these tubes in different stations, as can be seen in the in the figure. This transportation system will be continued inside the small torus segments just through the upper horizontal tubes (those under the residential level). These tubes, for the small torus segments with Space Ports, will end inside the Space Ports with a special station for each. Each station will serve as a passing point for passengers from the train to the space ship on the corresponding takeoff platform. In the storage area, there is another separate transportation tube. Inside the small torus segments, other elevators will provide communication between different levels of agriculture. Robots on Bellevistat have a separate transport system. Inside each torus segment, there is a robot maintenance area, linked with the other areas through an automated system of vertical tubes with elevators (different from the tubes for people and materials). There are 3 parallel tubes (one central and two on the exterior) at each 300 meters, so a total of 21 tubes for transporting robots for each torus segment. Things discussed in this paragraph can be seen in the picture below (Fig 3.2.4.1-half of torus segment), where blue means interior routes for transporting people and materials, green means routes for transporting robots, and red/pink represents station and routes for outer-torus transportation. The residential area surface also has streets for small electric cars, with limited speed (speed should not exceed 30 km/h) (see map from 4.1).

Space ships on Bellevistat have a separate transport system. Ships docked in Space Port C, before takeoff, enter one of the three systems of rails sustained by the two horizontal tubes each (one b and one c). On these tracks, the ship is tugged to the corresponding exterior Space Port, where the ship will enter one of the two takeoff platforms. The tracks are disposed lateral to the horizontal tubes, in order to allow the Coriolis force to be compensated by the normal interaction force with the tracks. Ships from Space Ports A and B will travel on the exterior of tubes a1, a2 and a3, on similar tracks, tugged by a similar system, and will be launched through the small Space Ports above each torus segment.

For transportation in the Central Industrial Area, a different system is used. The MovingPill(Fig 3.2.4.2 and Fig 3.2.4.3) is a mechanism with an octagonal shape, which has 5 special systems for fastening and moving on the resistance beams that form the structure. It also has rocket engines for movement and for reducing Torques caused by interactions with different beams. It also has four access points for people, and one bigger door in the upper part for loading other cargo. This utility can be used for transporting materials and people in different areas of the industrial zone and for surveillance of industrial activities in different sectors.

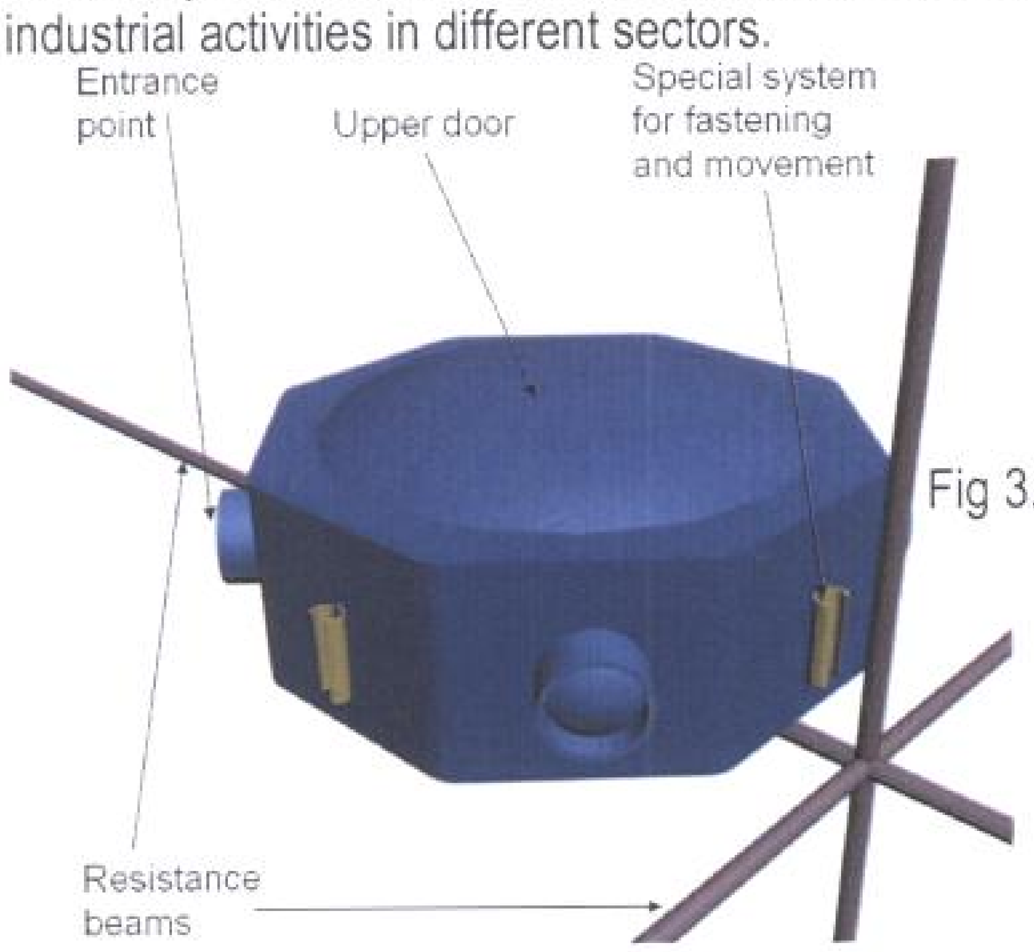


Fig 3.2.4.2

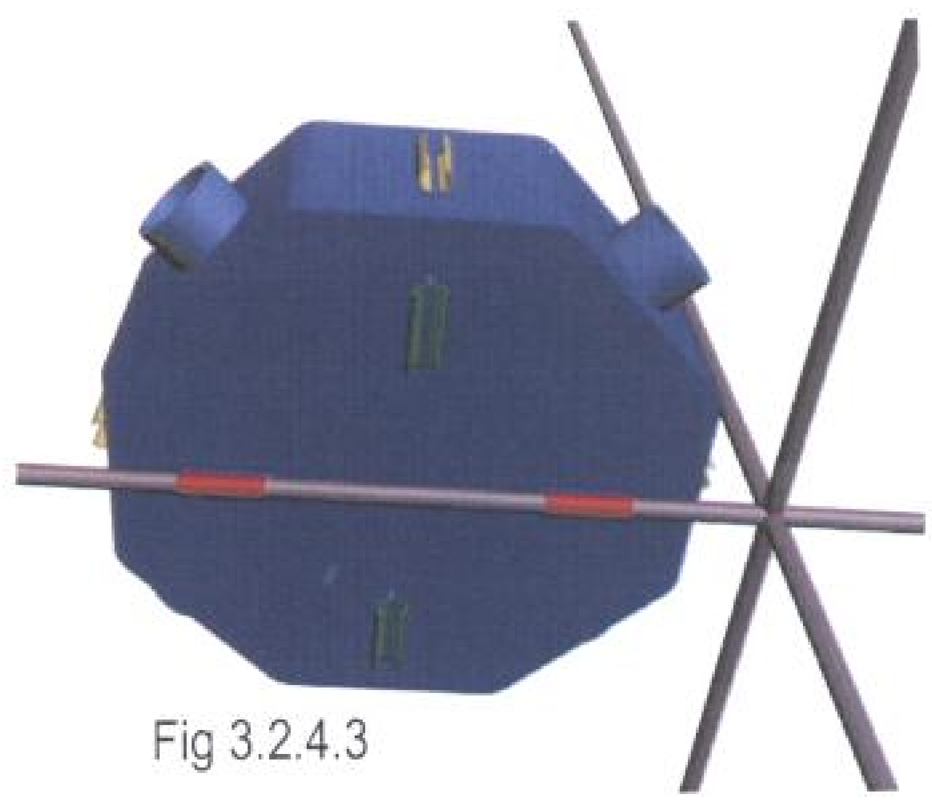


Fig 3.2.4.3

3.2.5 Atmosphere, climate and weather control

Gas	Percent	Pressure	Mass
Nitrogen	78%	79033.5 Pa	1,214,808,136 kg
Oxygen	21%	21278.25 Pa	373,787,119 kg
Carbon dioxide	0.03%	30.4 Pa	734,225 kg
Other gases	0.97%	982.75 Pa	21,581,757 kg
		101,325 Pa	

For providing suitable life conditions to its inhabitants Bellevistat needs to have an atmosphere of adequate composition and pressure. The human body system is based on the exchange of O_2-CO_2 gases with the environment, and its chambers and sinuses are kept from decompressing by the pressure in the atmosphere. The pressure level must be properly chosen, so the various life processes of humans, plants and animals in the settlement can be carried on properly.

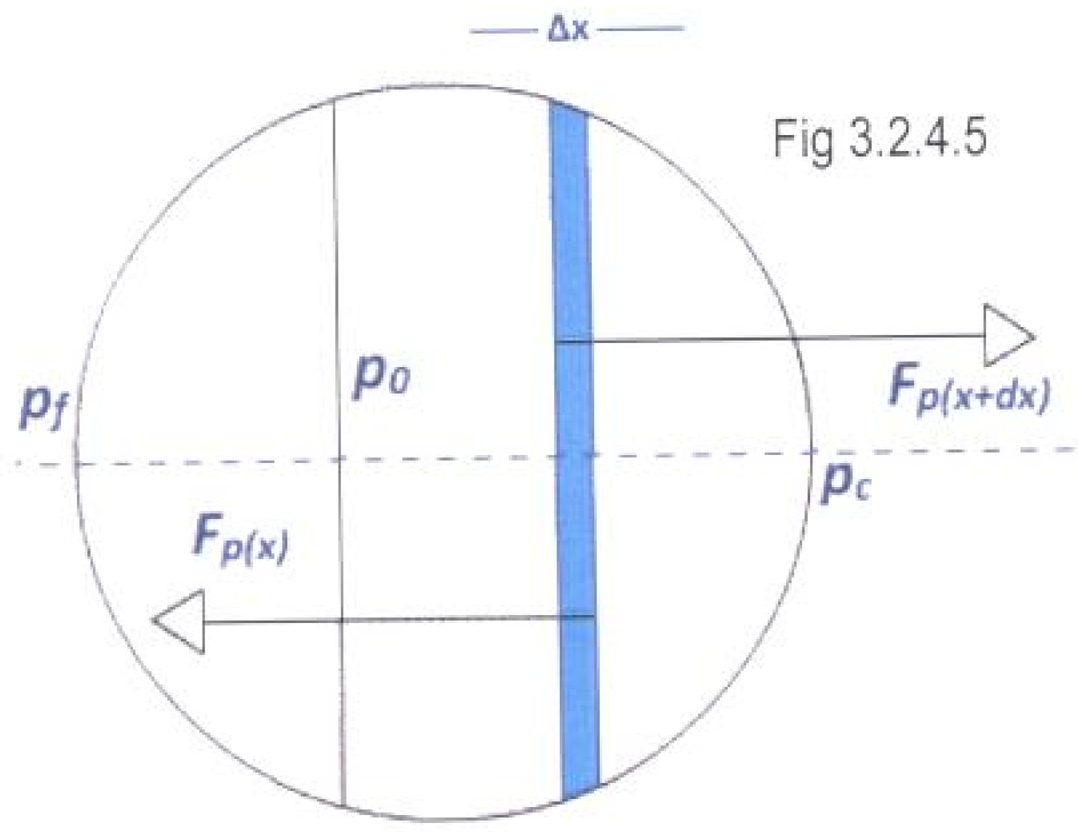


Fig 3.2.4.5

Also the carbon dioxide pressure should not exceed certain limits: a high pressure can be dangerous to human life processes, but a low pressure reduces the efficiency of plants photosynthesis. Although recent research shows that different atmospheric conditions can provide habitable conditions for short-term spaceflights, long duration exposure to such conditions can prove to be dangerous, so for the wide variety of life systems in Bellevistat, a risk-free choice is to have the same atmospheric conditions as Earth does.

Due to the fact that the atmosphere is in a rotating system, mechanical equilibrium requires the pressure to increase slowly from the closest distance from the axis to the farthest distance from the axis. We consider an element of thickness Δx, at distance x, from the rotation axis. This element of gas must be in mechanical equilibrium:

$$F_{p(x+dx)} - F_{p(x)} = dm\omega^2 x$$

$$\left(p(x+\Delta x) - p(x)\right)A = \rho A\omega^2 x\Delta x$$

$$\rho = \frac{p\mu}{RT}$$

$$p(x) + \frac{dp}{dx}\Delta x - p(x) = \frac{p\mu}{RT}\omega^2 x\Delta x$$

$$\frac{dp}{dx} = \frac{p\mu}{RT}\omega^2 x \qquad \int_{p_0}^{p}\frac{dp}{p} = \frac{\mu\omega^2}{RT}\int_{R'}^{r} x\,dx \qquad \ln\frac{p}{p_0} = \frac{\mu\omega^2}{RT}\frac{1}{2}\left(r^2 - R'^2\right)$$

The pressure takes the form $p = p_0 e^{\frac{\mu\omega^2(r^2-R'^2)}{2RT}}$ where (p_0 is the normal atmospheric pressure, R' – the distance from the rotation axis to the habitable main level, r is the distance from the rotation axis to the point where pressure is being measured, T is the temperature (in kelvins), R is the universal gas constant, ω the angular rotation frequency). Using the formula we find that the pressure at the closest point to the axis of the torus is $p_c = 0.97p_0$, and the pressure at the furthest point is $p_f = 1.014p_0$. The pressure variance is very small, negligible, so that the atmosphere is assumed to exert the same pressure everywhere in the habitable volume.

The initial amount of gas is pumped in the torus segments when they are finished. From the time the first life forms occupy them, the composition and pressure of the atmosphere must be held constant. This is partly realized by plants, which transform CO_2 into O_2 through photosynthesis and humans and animals, which consume O_2 and eliminate CO_2. In table cutarica the amounts are quantified.

Bellevistat is also equipped with auxiliary systems that eliminate, if necessary, amounts ofCO_2 and replace them with O_2. These systems are based on chemical reactions presented below, and "flow" the gases through fans into the life supported volumes of the settlement. The nitrogen is a very rare gas in outer space, so it is transported in large amounts from earth, as ammonia, to better use all the quantity.

$$NH_3 \rightarrow 3H_2 + N_2.$$

The hydrogen can be used in many ways, either to reduce the carbon dioxide, either to produce water or polymers.

$$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O + Q$$

The water vapors are condensed to form liquid water, which can be used as so, or can produce oxygen and hydrogen through electrolysis. The hydrogen is further used to reduce more CO2, and the oxygen is pumped into Bellevistat's atmosphere.

$$2H_2O \rightarrow 2H_2 + O_2$$

The lunar soil is very rich in oxygen compounds like oxides($FeTiO_3$, $FeCr_2O_4$, FeO) olivines(Fe_2SiO_4), pyroxenes ($Fe_2Si_2O_6$) or feldspars ($NaAlSi_3O_8$); oxygen can be easily chemically removed from these compounds.

$$FeTiO_3 + H_2 \rightarrow Fe + TiO_2 + H_2O$$

$$FeO + H_2 \rightarrow Fe + H_2O$$

$$2H_2O \rightarrow 2H_2 + O_2$$

The humidity and temperature are other two factors on which inhabitants comfort depends. A high temperature would make Bellevistat's inhabitants feel too tired, whereas a low temperature distracts residents and induces more stress on them. High humidity would make them feel suffocated but low humidity levels can dry the mucous membrane and lead to skin rashes. Temperatures in the range of 21-23 °C and humidity levels of 50% are kept around Bellevistat's habitable areas. However, each house is equipped with its own climate control system, able of creating a wide variety of environments so that the inhabitant feels comfortable.

3.2.6 Household and industrial waste management

All Bellevistat's resources must be used in a rational way, because the costs of importing prime materials from Earth are enormous. In conclusion all the wastes must be recycled, by different processes, or by chemical reactions decomposed in chemical elements. Recycling is a process of transforming old, used materials into reusable ones. It prevents the wasting of prime materials and reduces the energy consumption. A very common method of recycling is composting (the controlled decomposition of organic matter). The household water is flushed away and then chemically, physically multi-filtrated. The potable water has a more lasting process of filtration. The substances obtained through the filtration operation with the help of bacteria such as bacteria or thermophilic, hyperthermophilic bacteria, fungi and worms compost is produced, put in tanks, near the waste management area of the residential segment of torus, together with organic garbage from the agricultural area and asteroid soil, that it is cheaper lunar soil (regolith). In this way, by creating conditions that are are optimal for the development of decomposing bacteria and worms, the nutrients improve the soil with organic substances that have a smaller molecule, resulting in more aired, fertile soiled, a fertilizer improved according to the necessities of the settlement. Plastics recycling are more difficult because these materials are not biodegradable. The plastics are heated and melted, and then used to create other plastics so a polymer (a plastic) takes part at the inverse reaction of polymerization. This way the monomers resulted can be used to obtain other polymers. For glass recycling, less energy is consumed to recycle it than to produce new glass, the recycling means breaking the glass into small pieces and melting them at high temperatures. Aluminum recycling implies the melting of the metal, but is cheaper than producing aluminum by conventional ways. . In order to help the process of recycling, all the garbage cans on Bellevistat are divided into four sectors: organic matter, plastic, paper and metal like on Earth. There may be things that can be recycled in the sense of reusing them the glass bottles or the iron wire etc, and after the deterioration we use the further methods.

In the heavy industry area from 0g, the technique used tries to use all the industrial solid waste in different purposes and to avoid throwing it away (eg. After extracting the ores from the asteroid rocks, the debris is used as a construction material).

3.2.7 Water management

Reason of loss	Wasted Quantity/day (liters)	Method of recovery	Percentage of recovered water (%)
Water drunk by humans	35000	Humans' urine and perspiration	90
Food preparation	55500	Pipes and evaporated water	90
Clothes washing	24000	Pipes and evaporated water	95
Bathroom activities	370000	Pipes and evaporated water	100
Plants watering	4000000	Pipes for unused water , plants' perspiration and humans' and animal's urine	80
Water drunk by animals	500000	Animal's urine and perspiration	90

Spaceship cleaning	2	Evaporated water	100
Industry	40000	Pipes and evaporated water	100
Production of liquid oxygen and hydrogen	70000	Not recovered	0

At the beginning, the settlement will have a quantity of 20000 tones of water in order to support all the needs for a period of time of one year and to fill in all the fish ponds and pools. Because the spaceship is perfectly closed and, therefore, does not permit water to exit it, the percentage of lost water will be, with the exception of the water used in the production of liquid hydrogen and oxygen and of that sold to the temporal tourists, less then 10%. However, the spaceship will have to refill its water supplies from time to time with supplies brought from earth with transport ships.

In order to contribute to the torus segments' autonomy, they will each be equipped with its own water tanks, pipes and a purifying water system, situated in the light industry area. Also, there will be another central water tank inside the central cylindrical unit. Through each spoke, a water pipe will pass and enter the light industry zone through one water tank. From these two water tanks, water pipes go to each neighborhood, from where will be send through smaller pipes from water distribution facilities.

A lot of the lost water will be collected by pipes from people's bathrooms and kitchens and sewerages. The remaining evaporated water will be recovered by an advanced condensing system which will monitor and keep the water percentage in the air at normal. Near each water distribution facility, another recycling facility will resend purified water to the water tanks.

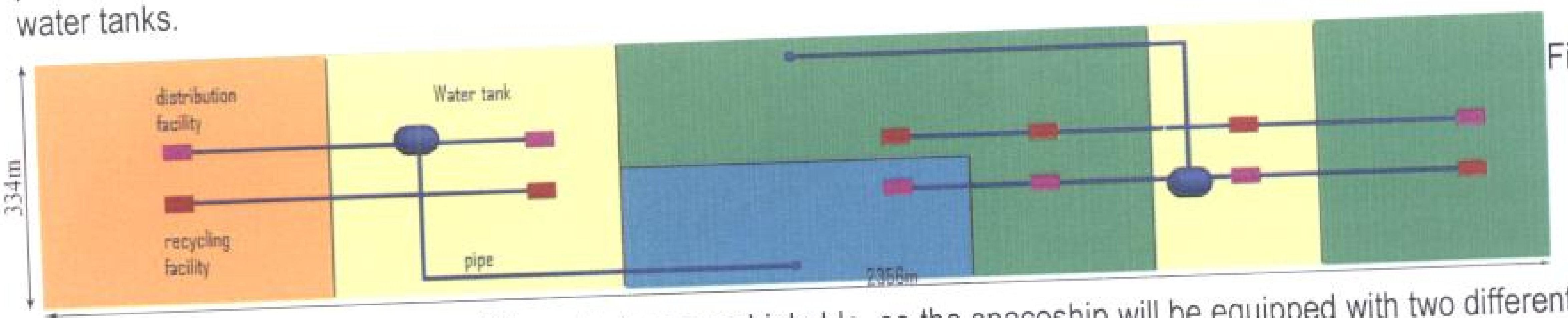


Fig 3.2.7.1

The recollected water will have to become drinkable, so the spaceship will be equipped with two different water purifying stations, one using the conventional method, and the other a new one based on nanotechnology, which is able to clean the water to the smallest degree and, therefore, will clean the water polluted by the factories.

The first method will be used to purify water coming from the residential and agricultural areas and will include ph adjustment, to keep the ph at 7, flocculation, to clarify the water, sedimentation, to allow the flock to settle to the bottom, ultra filtration, to filter the water using polymer film with chemically formed microscopic pores and disinfection to remove possible pathogens by filtering out the microbes and by adding disinfectant chemicals to the water.

3.2.8 Day/night cycle provisions

Because the torus has solar panels on its exterior which obdurate the direct solar light, the transmission role of natural light to the interior of the segment of torus is taken over by the special shaped mirror situated in 0 gravity, to which the sun rays arrive directly, that provides natural sunlight to the settlement's inhabitants by reflecting incoming solar light to the main level of the residential and Bellevue agricultural torus segments, through specially designed windows.

The mirror is composed of modular, small (4m x 4m) mirrors, attached to the outside of the sphere-like structure. At one side of each of these panels, there is material wrapped up, that will cover the mirror panel when night is due on the torus sections. In fact it is simulated a night sky with the help of holographic projections.

The period of such a night can be adjusted depending on the schedule, but taking into consideration that the human body is adapted to a 24 hours circadian cycle, we have chosen this for our residents too. The whole settlement will have the same schedule, there will be residents that work in shifts, so that it's activity will be permanently supervised, and we took into account the fact that touristic, commercial visits that would be affected in case of 3 different time zones.

3.3 Space infrastructure

As the main space manufacturing center in Earth's orbit, Bellevistat must be sustained by a variety of vehicles and facilities placed on the Moon or on asteroids.

Percherons are the main launch vehicles capable of transporting materials from Earth's surface to the spaceports placed in LEO (low earth orbit). They are used for transporting some of the construction materials for Bellevistat, and during its operation are used for trading purposes. They are powered by liquid O_2 and H_2 fuel thrusters.

Palominos are the main vehicles used for human transport. They transport the population of Bellevistat. Their fleet size is adjusted to the demands of space tourism on Earth, and they are also used for transporting Bellevistat's residents to Alexandriat, Moon outposts, or future settlements. They are powered by liquid O_2 and H_2 fuel thrusters.

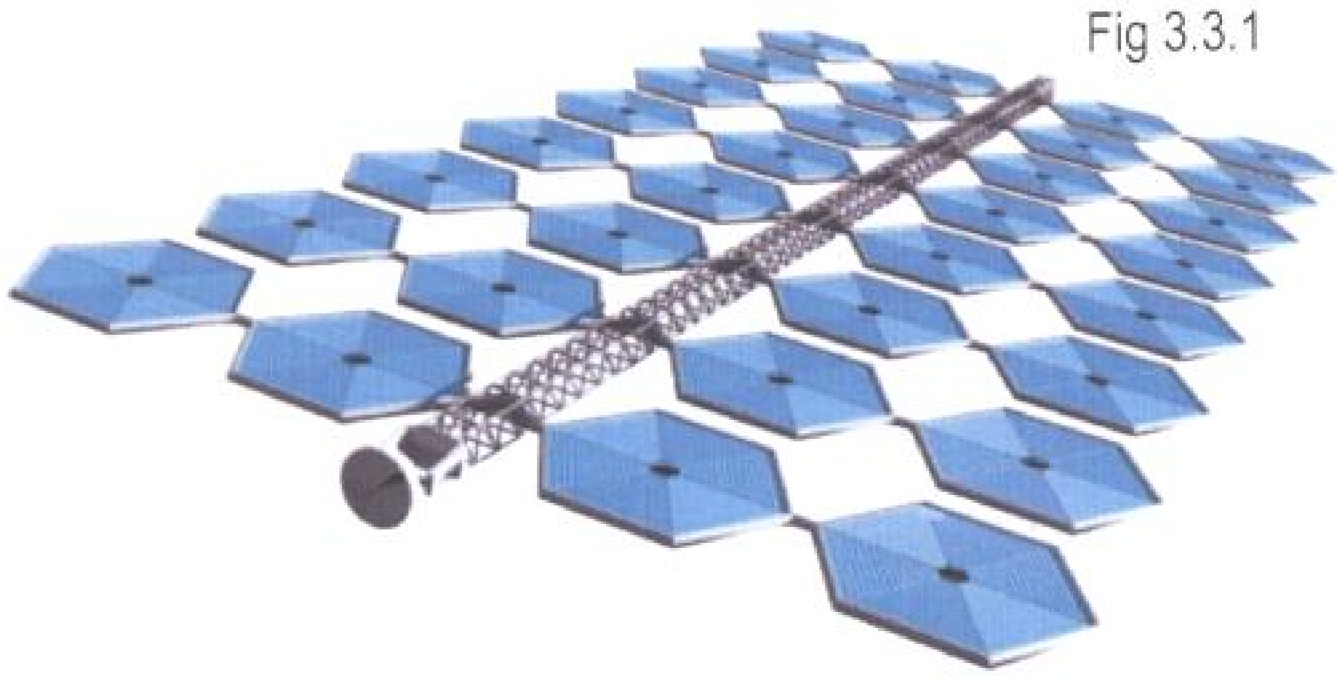


Fig 3.3.1

Solar power satellites (Fig 3.3.1) provide power (transmitted by microwave) to Bellevistat (if needed), lunar outposts, mining facilities or to other facilities owned by corporations. Some are placed in orbit around the Moon, to sustain the mining operations that take place on its surface, others follow some asteroids on their orbit and support the operations performed on their surface. Most of them are used for commercial purposes by providing power to Earth's facilities. They use ion engines for various maneuvers.

Space Tugs provide the assistance needed to damaged ships, or move low illuminated satellites to higher or lower orbits. They either repair them in space, if the damage is small, or they transport them to Bellevistat's spacecraft maintenance areas. They are powered by liquid O_2 and H_2 fuel thrusters.

Communication support satellites are placed to strengthen the signal between Bellevistat and Alexandriat, as well as between the settlement and its entire infrastructure, thus providing the means for properly coordinate operations from a long distance. For small corrections they use ion engines.

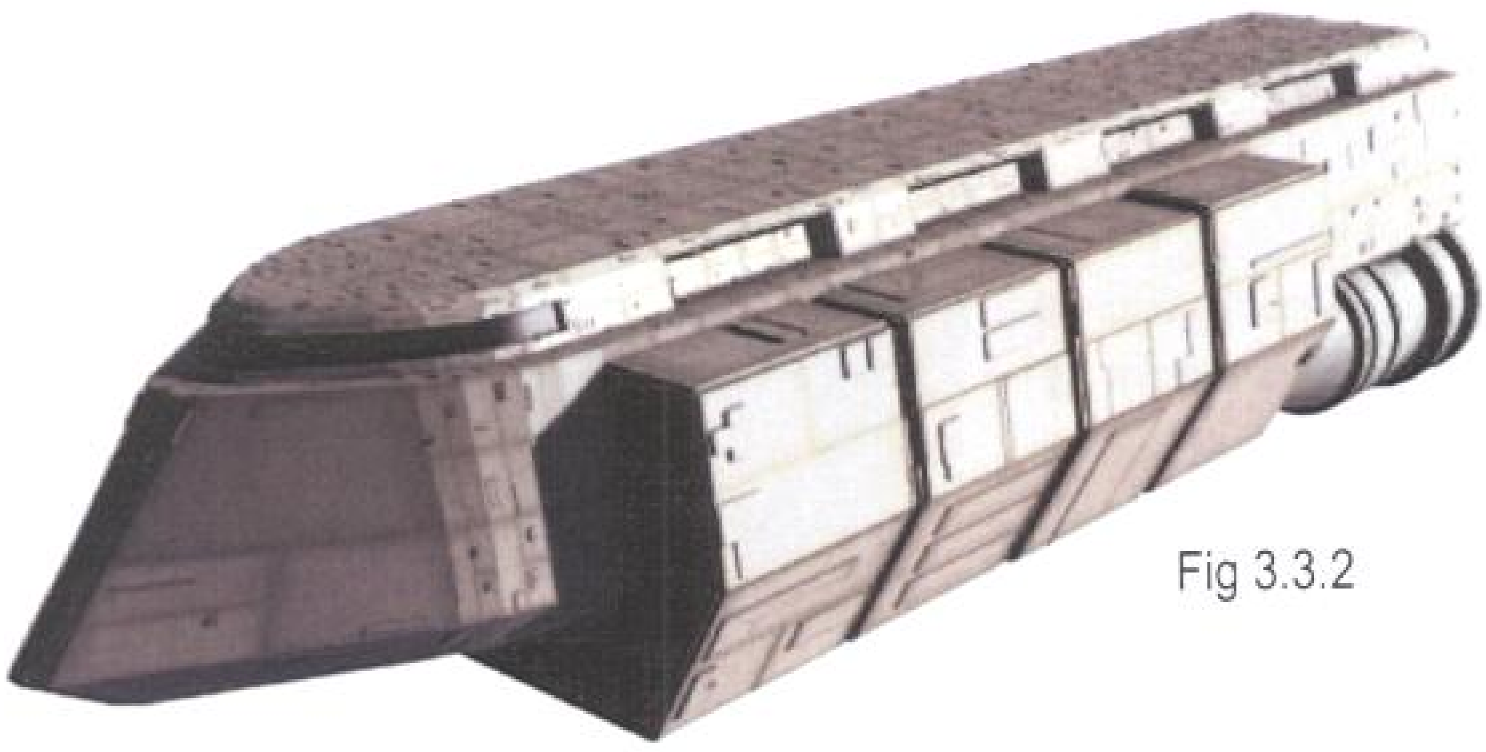


Fig 3.3.2

Cargo ships (Fig 3.3.2) assure the transport of materials above LEO. These ship materials from the lunar surface, and are used to transport equipment and some materials from Alexandriat. They are powered by liquid O_2 and H_2 fuel thrusters.

Obots are multifunctional robots that assist the settlement's operations and make sure everything goes as planed. They clean the space dust of the layer of solar cells, repair settlement damaged sections, etc.

Explorers as their name suggest, explore from up close space objects, by identifying the internal structure of asteroids, or comets, thus providing important information as to where to place the mining facilities. Some are even sent in the outer part of our solar system, while others are used to better determine the structures of planets. Many have high-accuracy photographic systems attached, and send their photos to Bellevistat research facilities. Their small size allows the ion engines to be very efficient.

The commercial vehicles dock in Space Ports A, B and C while the industrial vechicles carrying cargo dock in the mirror's industrial space port. Some of them, if destination permits, are launched from one of the three launching ports, or from the arms using the settlement's rotation speed, and in this way saving fuel.

Asteroid mining facilities are presented in more detail in section 2.4. They are used to mine asteroids at a cheap cost, to enrich commercial development of Bellevistat.

Lunar Outposts provide important materials for the construction of Bellevistat, and further for the the commercial development of the settlement. They are placed in various locations on the Moon surface and powered by solar power plants around them and Solar Power Satellites. Their main objective is to obtain oxygen, for Bellevistat's atmosphere and, silicon for solar cell construction. They also harvest for metals, hydrogen, and carbon compounds.

Bellevistat's fleet size and number of facilities change according to economical demands.

Infrastructure/Vehicle	Number	Payload size	Range	Contract inclusion
Percherons	20	18,200 kg	420 km	Yes
Solar power satellites	50	-	100,000 km	Some, others commercially developed
Palominos	60	80 passengers and 9,100 kg	350,000 km	Yes, others developed to sustain space tourism
Space Tugs	25	20,000 kg	300,000 km	Yes, some commercially developed
Communication support satellites	15	-	200,000 km	Yes
Cargo ships	20	10,000 kg	400,000 km	Yes, some commercially developed
Obots	200	-	Settlement	Yes

			perimeter	
Explorers	15	-	Unlimited	No
Asteroid mining facilities	3	-	Asteroid surface	Yes, some commercially developed
Lunar outposts	15	-	500 km	Yes, some commercially developed

3.4 Animal feed and facilities

In order to have an efficient land use and create a friendly atmosphere on Bellevistat, the landscaping is present not only in the Bellevue area, but also in the residential and commercial areas. The residents have the possibility of growing their favorite plants, flowers, spices, fruits, vegetables, trees (all of these must not be higher than 5 meters, it's a matter of security) near their houses, being not only a matter of space utility, but also a psychological one. Bellevistat has a politic of encouraging its human inhabitants to buy different plant species from Earth, in this way it is created a so called "Bellevue plant ark".

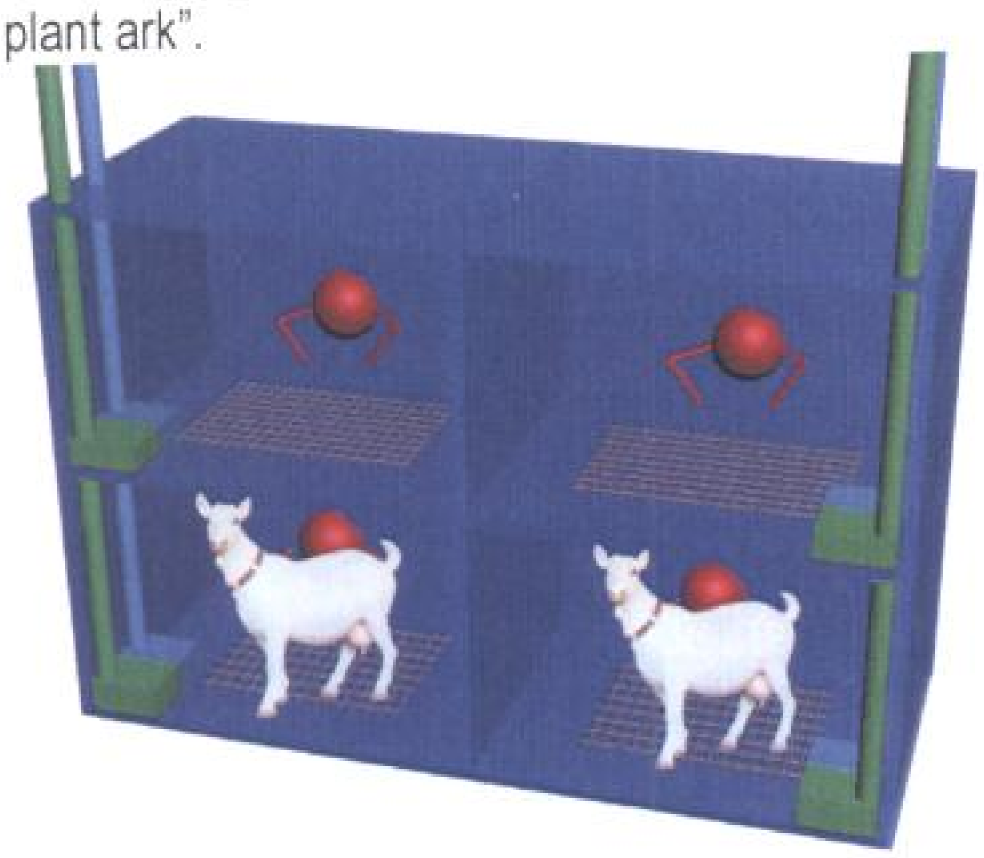


Fig 3.4.1

On the other hand the residents aren't allowed to raise any kind of animals in the resident area, just in the Bellevue areas where they can see fish grown in many small pools, rabbits, sheep, goat, chicken… a mini zoo! These means of protection are for the lack of hygiene, that the raising of animals may cause and for the eventual accidents (ex. Birds flying in the residential areas look really nice, but these may cause serious accidents and/or die quickly because of the artificial gravity and their flying which is affected by the lack of magnetic field, plus they eat the plants/fruits/leaves/flowers destroy beautiful surroundings).

In conclusion it is the best for the health and security of the Bellevistat's residents, that animals are grown on the 10th and 4th floors from each segment of torus. Their feed is closely situated on the floors above and it is provided by the agricultural robots that collect it, pack it, and deliver it from one floor to another through the infrastructure transportation corridors, after this through the feed, water pipes. When it arrives, the feed is given taking in consideration the animals' special necklaces that establish the quantity of food and water that they need. A multipurpose automated system deals with milking, egg picking, and hatching, checking their health periodically, vaccination and even slaughter. The hygiene system cleans their area in order to prevent epidemics. The animals receive a necessary surface in order to live under optimal conditions that fit their dimensions (ex. The goat's cage measures 1,25 height, 1,5m long and 1m wide; Fig 3.4.1). The only purpose of the human workers in this area is to supervise these processes and from time to time to check their blood analysis in the Laboratory no 2.

Table with facilities for the animals raised on the settlement

Species	Food/ animal/ day	Water/ animal/ day	Vaccine/ year	Special care	Hygiene / day	Delivery/ monthly/ /pers	Picking of eggs/animal/ day	Milking /animal /day
Tilapia (fish)	100 g soy beans	$0.5m^3$	-	Treated water	1	12	-	-
Carp	100 g soy beans	$0.5m^3$	-	Treated water	1	13	-	-
Rabbit	100 g soybeans 20 g corn	0,5l	2	Fur collecting	3	2-3	-	-
Sheep	6 kg cereals	1l	3	Fur collecting	3	0.2	-	3l
Goat	6 kg cereals	1l	6	Fur collecting	3	0.2	-	3l
Chicken	150 g soybeans	150ml	2	Feather collecting	3	5-6	0,5	-

Ornit quail(coturnix coturnix)	80 g soybeans	25 ml	1	Feather collecting	2	1-2	0.5	-
Duck Cairina Moschata	90g Maze	200ml	2	Feather collecting	2	0,5	0,3	-

3.5 Materials

In order to conserve and efficiently use resources, the materials are exploited from the L4 asteroid because, due to the shorter distance and lower gravity, they are more economic than those from Moon or Earth. Also, the secondary products resulted from industrial activities, such as heavy industry: foundry ashes; light industry: straws, cellulose, animal bone glue, are used for obtaining different materials needed for buildings interiors: hardboards, plumbing and cases. A big amount of cellulose is brought by the water hyacinth used for zoo culture water purification, which has a large capacity of biomass. In the table below are described the utility of several materials:

Material sources for houses	Utilization
Water Hyacinth	Furniture
Cermet	Walls
Composite materials	Miscellaneous news
Teflon	Household apparatus
Aluminum	Household apparatus
Stainless steel	Vessels
Polymers	Pipes
Glass	Screens, monitors

Material sources for amenities	Utilization
Water Hyacinth	Furniture
Cermet	Walls
Composite materials	Miscellaneous news
Polymers	Pipes
Iron alloys	Stadium resistant structures
Synthetic fibers	Cinema screen
Rubber	Hospital apparatus

4. Human Factors

Bellevistat internal infrastructure offers all basic comfort, and a variety of facilities to reduce stress from living in a closed system, with both living and working conditions different from Earth. Solar light, space observation, interactive games in 0g environments, the diversity of the residential torus segments, a safe and pleasant environment are just a few of the wide collection of facilities that Bellevistat's residents enjoy.

4.1 Community design

Residents order their food through the DelSys, (an internal delivery system), and payment is made automatically through cards. This system is used for ordering food, and other necessities, like clothing, house utilities, through Bellevistat's internal network. Every house is also equipped with a kitchen that allows residents to cook what they obtain from their backyard "crop".

Resident clothing is made out of natural fibers – cotton and line.

Each house has its own collecting system in the bathrooms and kitchens connected with corresponding Recycling Centers, according to materials thrown. The waste is transported to the Recycling Center, when the house garbage recipient is filled.

Backyard gardens surrounds resident's houses, where they can grow plants for their own use, flowers or can arrange it according to their personal tastes, to reduce environmental stress. Bellevistat's interior arrangement offers residents parks, where they can relax, theatres where they can enjoy themselves, or restaurants, pubs. Each torus residential segment supports the children population by offering them high quality education, very important to their development in space. The healthcare system's staff monitors every resident's evolution and adaptation to the settlement environment.

For getting around the settlement a variety of transport means are available: tricycles, small electrical cars, roller skates. These provide stability, thus avoiding orientation problems due to Coriolis force.

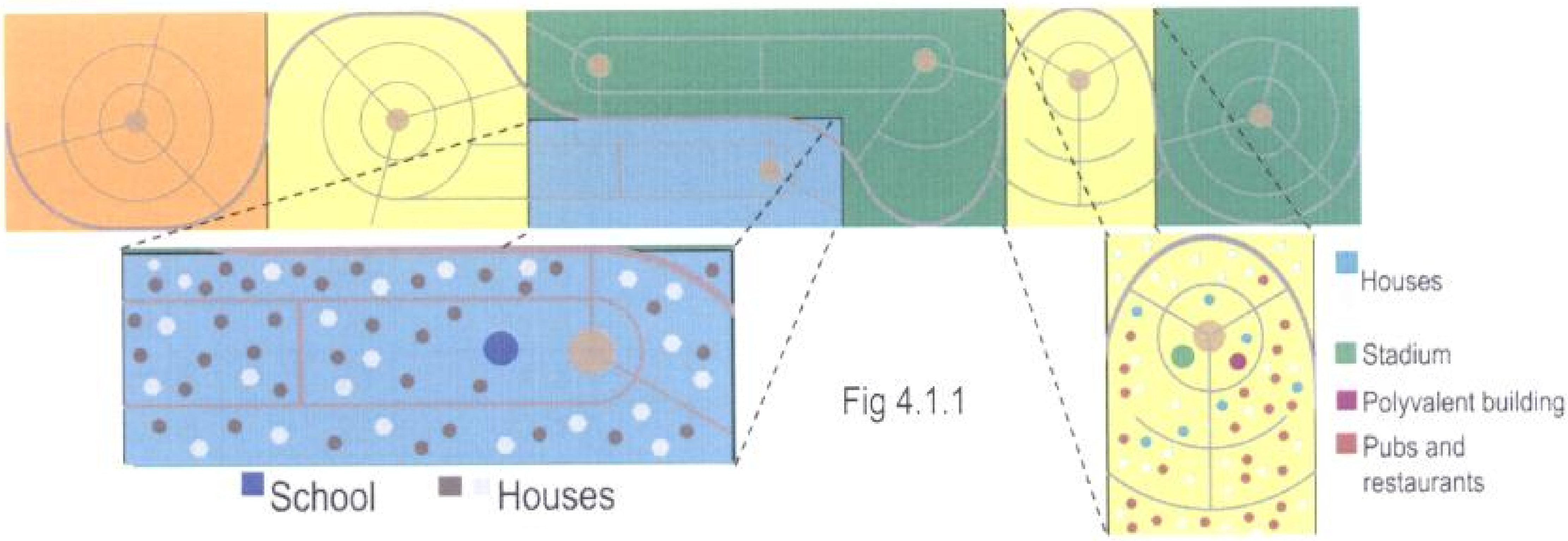


Fig 4.1.1

Roads - 14%
Paths - 2.36%

4.2 Residential design

Houses of Bellevistat's inhabitants are spherical because the sphere has the best volume to lateral area proportion rate. Thus, people have enough space to get by, enough liberty in his own house without the need to spend a lot for house because it requires little amount of material. Also, the circle is the symbol for the Universe, the Sun, equilibrium and the circle floor plan for each level has a benefic influence over the human psychic. Without having a beginning or an ending, it doesn't present a specific division so it has a lot of modular possibilities.

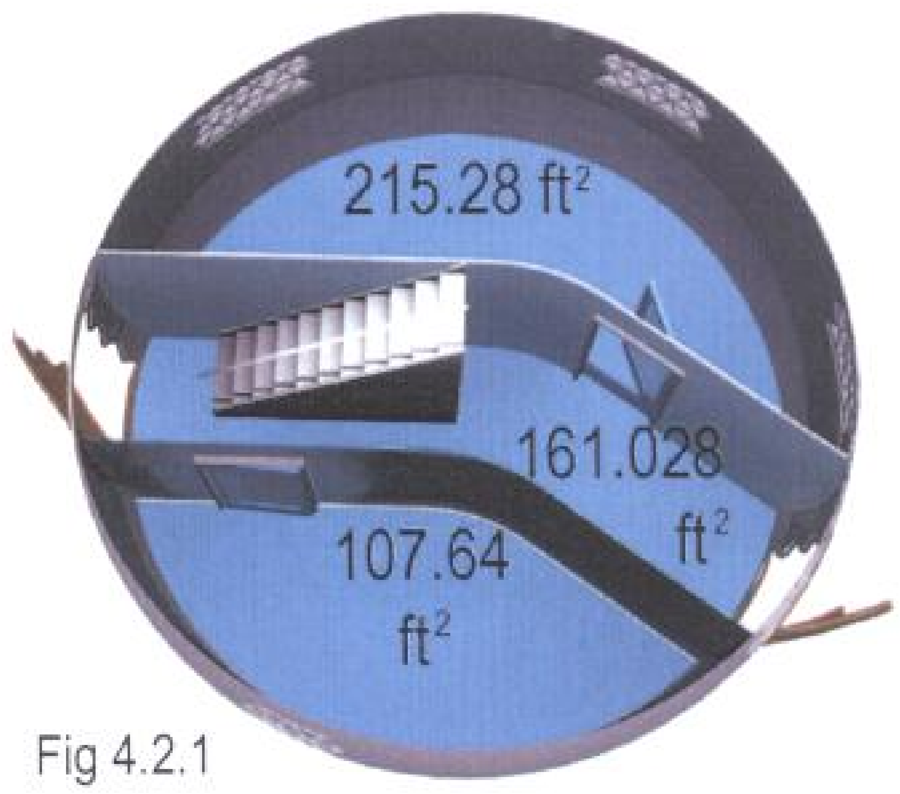


Fig 4.2.1

Initially, Bellevistat comes with five house models according to individuals' needs. These can be rearranged afterwards as preferred.

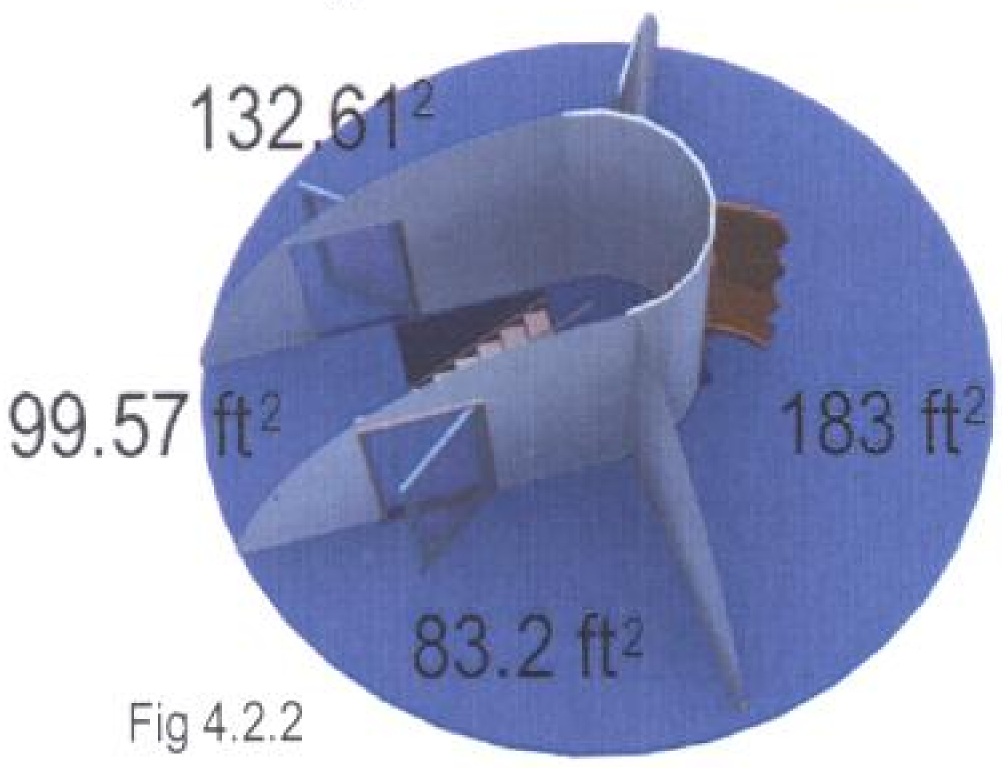


Fig 4.2.2

For the three spherical hose models (types 1, 2, 3) the floor was lowered by 1.4 – 1.5 m from the middle plane of the sphere so that the visual angle is bigger, fact which creates psychical comfort. We avoided adding levels so that people would not feel the effects of the Coriolis force. This is why houses only have first and second floors, eventually a garret at the third floor.

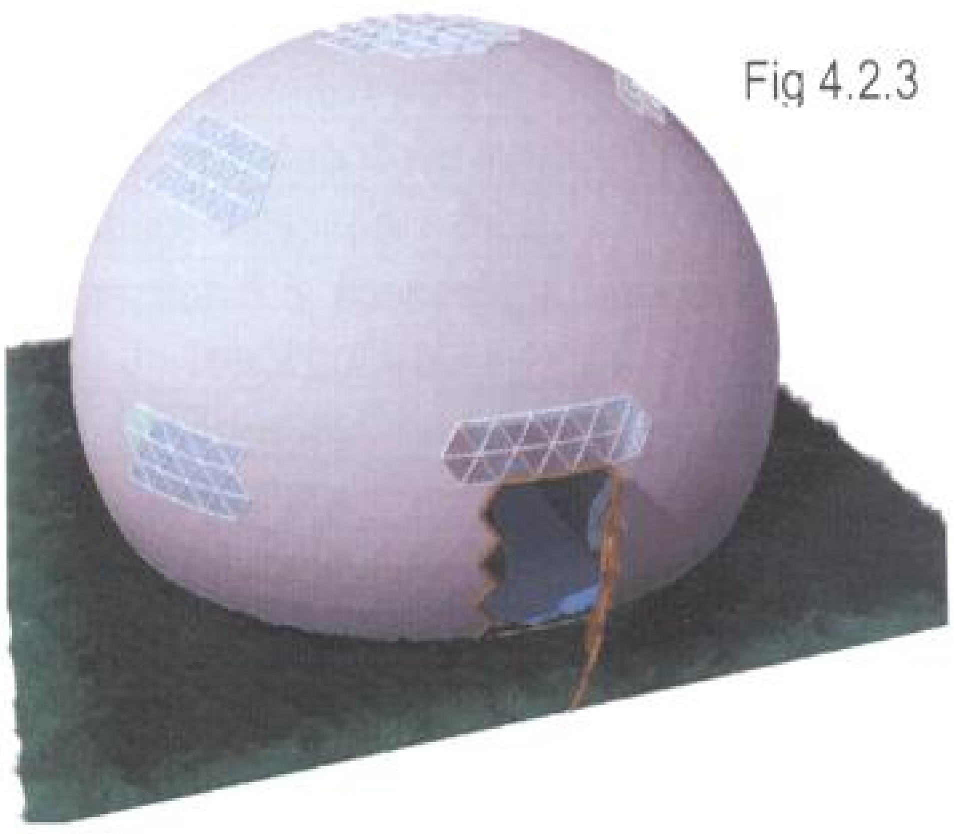


Fig 4.2.3

The walls are made of triangular structures which are easy to assemble and disassemble. This fact offers modularity to houses. People can modify the internal arrangement, room sizes or they can create a new room by adding a wall. For the type 4 houses one larger home can be obtained by merging two separate apartments.

Houses are built from composite materials as cermet.

The house furniture is manufactured from Water Hyacinth, and it is modular as well. It can be assembled into different shapes, according to necessities.

House	Nr of persons	Nr of houses	Note
type 1 sphere	1-2	7500	7000 single and 1000 living 2 by 2 (500 houses)
type 2 sphere	2	2800	4600 married (2300 houses) and 1000 living 2 by 2 (500 houses)
type 3 sphere	3-4	240	200 having one child (100 houses) and 280 having 2 kids (140 houses)
type 4 sphere/8	1	3600	3600 single
type 5 hexagon	2-3	160	320 having one child (160 houses)
Total		**14300**	

House	Radius (ft)	First floor (ft²)	Second floor (ft²)	Garret (ft²)	Total (ft²)	House ground (ft²)	Garden (ft²)
type 1 sphere	13	473	499	0	972	1302	830
type 2 sphere	16,5	766	809	541	2115	2110	1344
type 3 sphere	20	1138	1181	676	2994	4306	3169
type 4 sphere/8	23	415	311	0	725	1301	889
type 5 hexagon	23	1371	0	0	1371	3488	2118

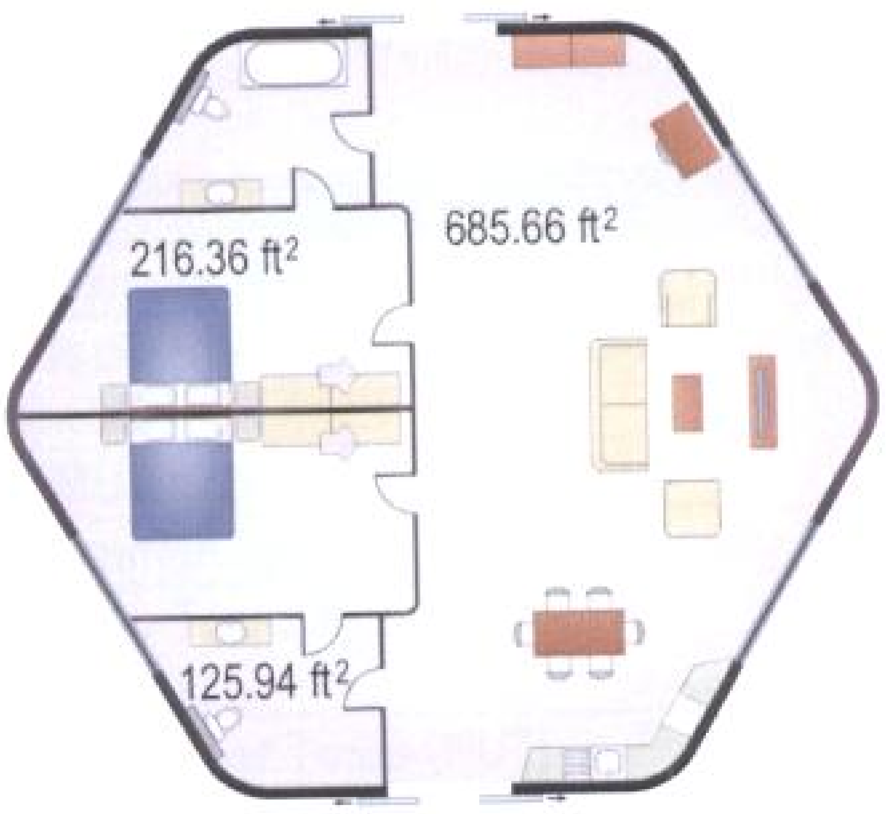


Fig 4.2.4

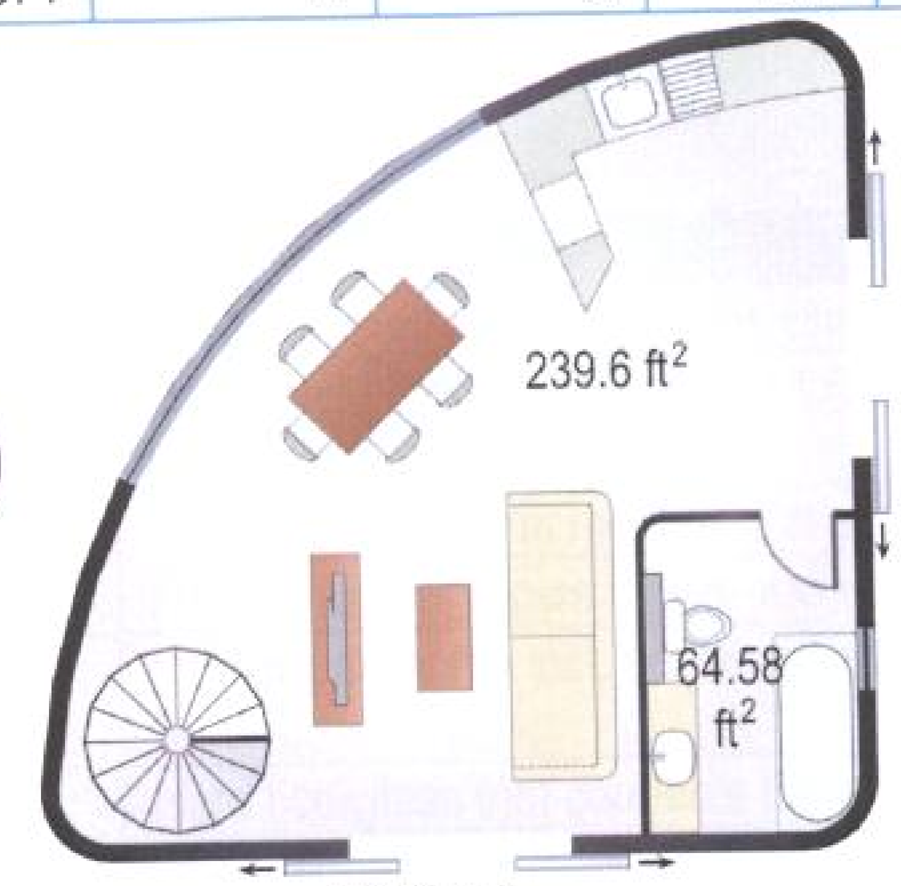


Fig 4.2.5

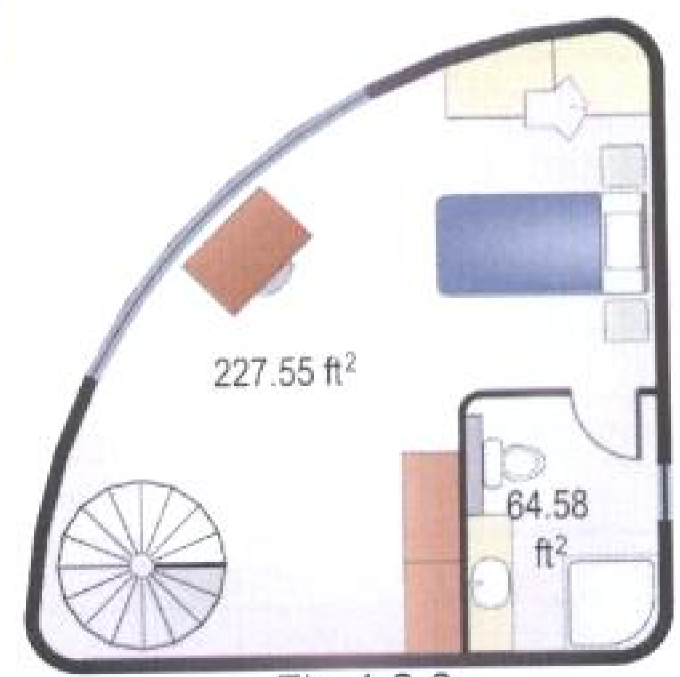


Fig 4.2.6

4.3 Work Environments

Type of Work	Needful tools
Agriculture workers	GPRB-based robots (see section 5.2)
Manufacturing	industrial robots
Agriculture	agricultural robots described in section 5.3
Workers outside the settlement	spacesuits, spaceships
Mining	mining robots described in section 5.5, spaceships, spacesuits, apparatus for robot control
Maintenance	GPRB-based robots
Doctor	documentation , medical equipment, medical supplies
Engineer / Researcher	Computers with corresponding software, apparatus for robot control
Cook	receipt, kitchens, delivery system
Education	eLearning software, computers , didactic equipment
Low-g Workers(for short periods of time)	Magnets in the sole of their shoes
Merchants	software, e-commerce site on Bellevistat's network , computers, delivery system
Psychologists	computers, documentation, statistics about what people eat, buy, do etc.
Financial analysts	statistics about the evolution of the financial data
Robotics workers	industrial robots, physics simulation software, testing equipment
Programmers	computers, documentation, Application programming interface for controlling robots' functions, testing equipment
Surveillance workers	Command panel for the areas and the
Construction workers	Robots, plans made by the architects, apparatus for controlling the robots
Managers	Exhaustive statistics about settlements economy status from the financial analysts, statistics about people's mental status from the psychologists and physical shape from the doctors etc.
Delivery system workers	Operating card actions permission, underground rail system, GPRB-based robots
Architects	3D modeling software, multiple processing units for real time rendering

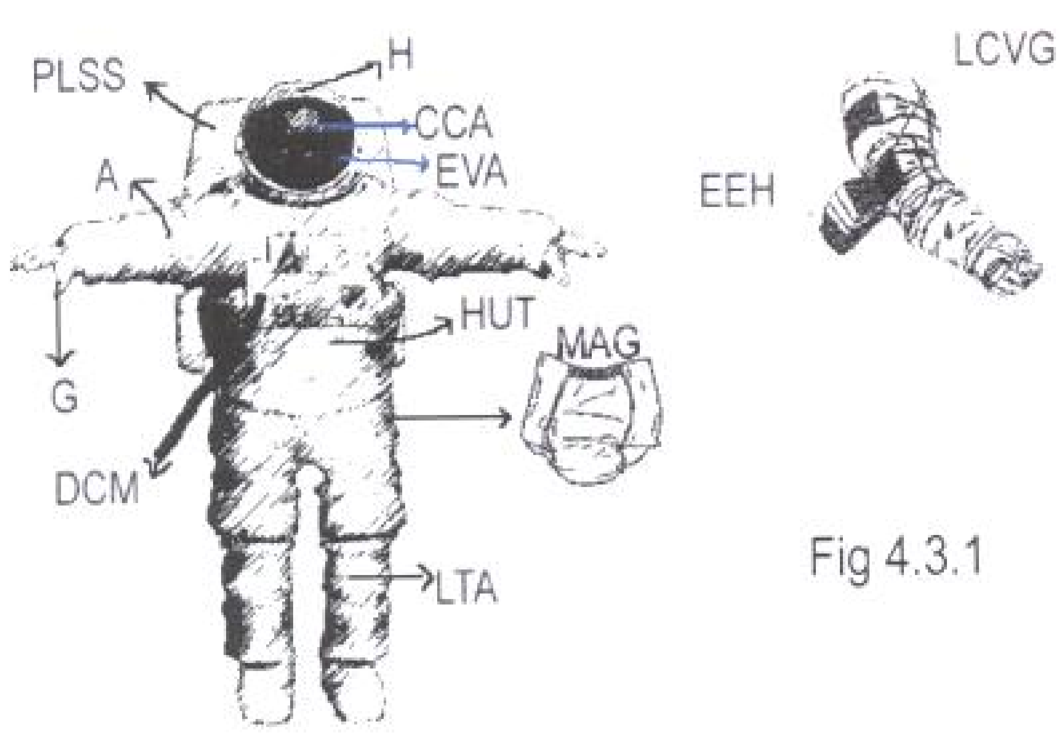


Fig 4.3.1

Inhabitants that go outside the settlement need a suit to offer them mobility. This suit is made up of several layers of nylon and spandex, very resistant elastic materials, polymeric gel and silver, which emits ions, thus killing bacteria. The suit also holds a rigid skeleton that ensure the pressure needed by the inhabitant in the outer space void.

Component	Description
Maximum AbsorptionGarment (MAG)	Kevlar diaper for absorbing the urine
Liquid Cooling and Ventilation Garment (LCVG)	Nylon and Spandex layer that allows cold water to flow through tubes, cooling the body
EMU Electrical Harness (EEH)	Bio-instruments that monitor vital signs
Communications Carrier Assembly (CCA)	Fabric cap that allows hands-free communication
Lower Torso Assembly (LTA)	Inferior part of the suit, containing pants, knee joints, ankle, boots, lower waist
Hard Upper Torso (HUT)	Hard fiberglass that connects the other components
Arms (A)	-
Gloves (G)	Ensures better grip
Helmet (H)	Plastic polycarbonate, impact resistant
Extravehicular Visor Assembly (EVA)	Light filtering
In-suit Drink Bag (IDB)	Water recipient
Primary Life-Support Subsystem (PLSS)	Oxygen, carbon dioxide tanks, batteries, cold water
Secondary Oxygen Pack (SOP)	Oxygen supply pack, sufficient to sustain breathing 30 minutes
Display and Control Module (DCM)	Controllers for the PLSS

4.4 Neighborhood differentiation

For more diversity, we conceived many types of houses, so that people can choose what best suits them. Of the 5 types of houses, 3 are spherical, one is the eighth part of a sphere and another one has six sides. Also for diversity we designed four different neighborhoods as follows:

Educational neighborhood

Contains most of the family with children houses but other educational institutions as well (school, high school, etc). Because it is an area with lots of children there are also many parks and recreational areas. The neighborhood has an area of 97823 m^2, meaning 11.54% of one of the residential segment area.

Fig 4.4.2

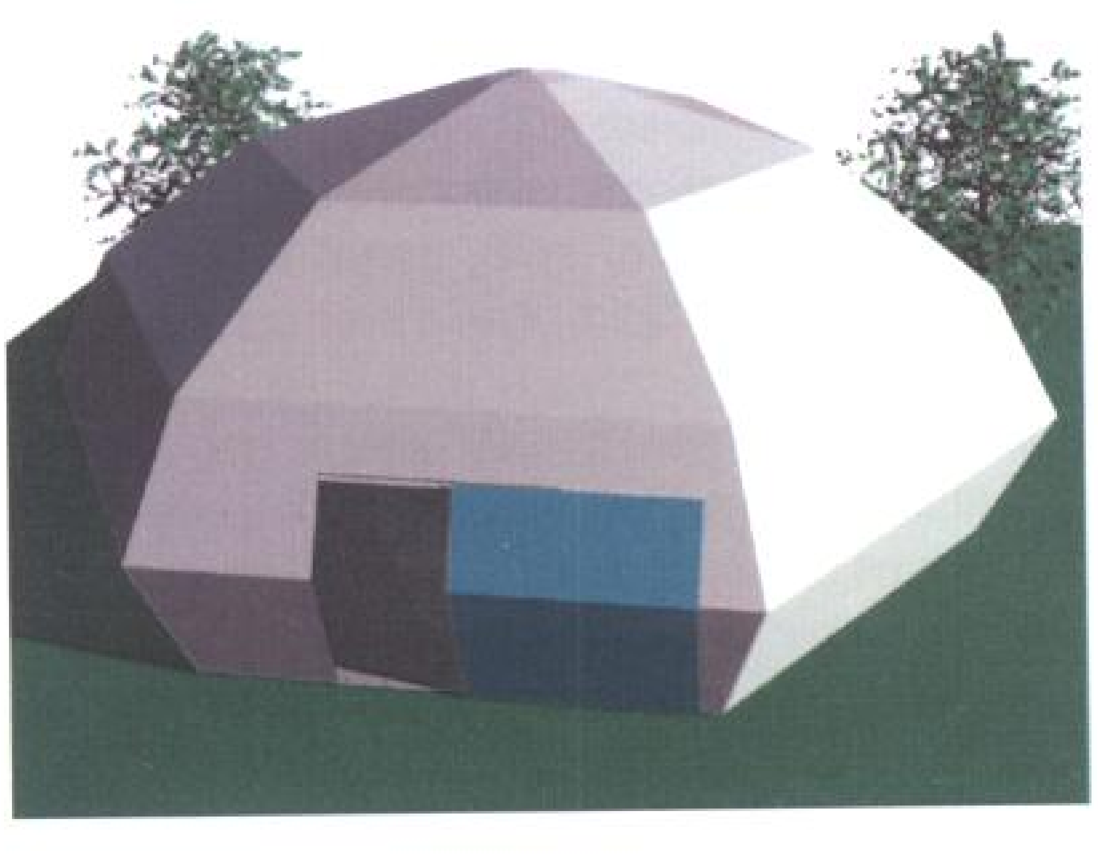
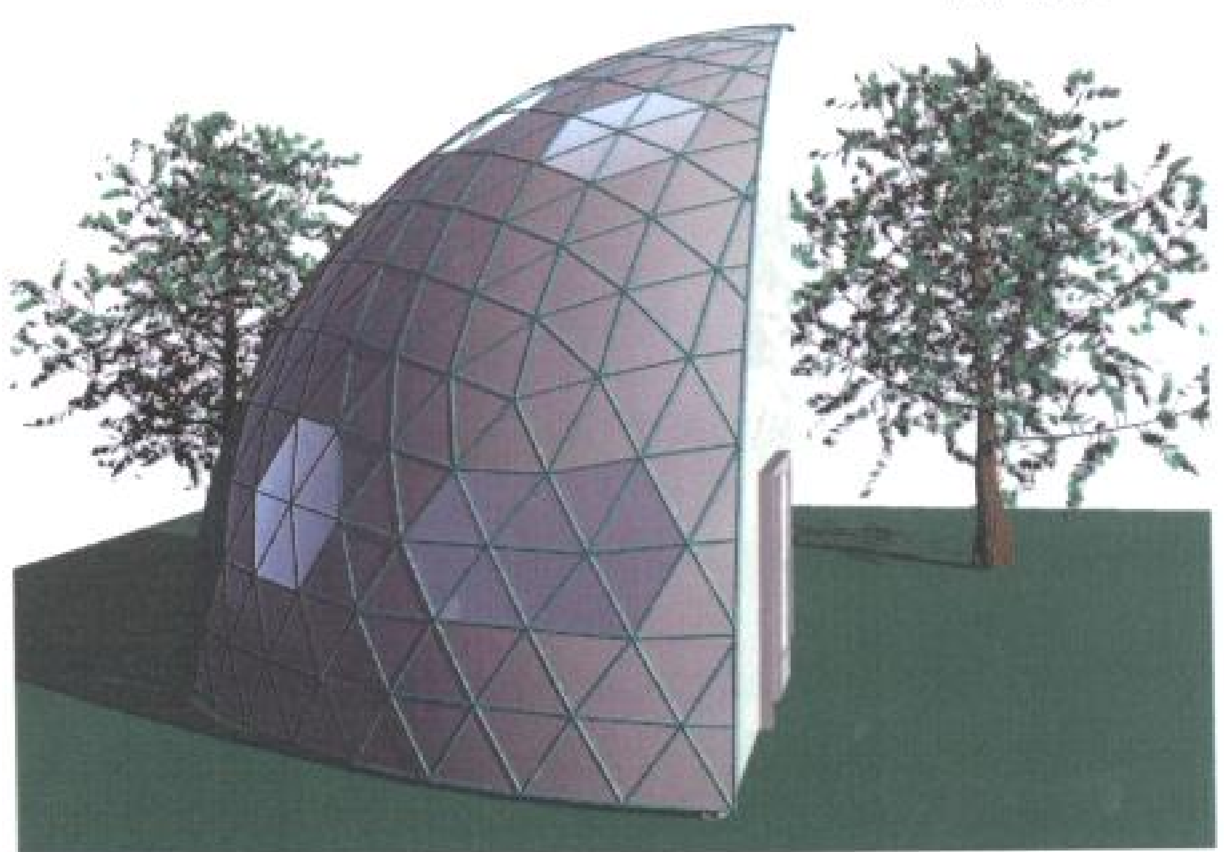


Fig 4.4.1



Touristic and Commercial neighborhood

Contains the hotels destined to tourists but also shops, a museum and some pubs. To familiarize with the settlement, a sights man takes a touristic tour to the visitors, presenting them the particularities of Bellevistat, miniaturized representations of settlements systems and processes. The neighborhood has an area of 163038.5 m^2, meaning 19.23% of the residential area of a torus segment.

Entertainment neighborhood

It is the most important neighborhood because here people have a lot of facilities. It is divided into two parts that are to be placed in two different sides of the residential segment. Thus, it is the only neighborhood connected with the other three as it is the most interesting. Here are located the stadium, the polyvalent building (cinema, theatre), relaxing centers, large parks, pubs and restaurants. It occupies 260861 m^2, meaning 30.77% of the residential area.

Common neighborhood

Is the largest neighborhood so that the majority of people which have no kids or does not like the bustle, can live in a quiet place. It contains very large parks and a lot of decorative elements, such as flowers and gardens, but also a hospital. This neighborhood occupies 326077 m^2, meaning 38.46% of the residential surface.

The neighborhoods were conceived so that the Touristic would be connected only with the Entertainment in order not to break in on residents from Educational or Common. The latest were divided into two parts so that the residents from one side of the Common would not be too far from the facilities provided by Entertainment. Educational is placed in the center of the residential segment so that the children of the families which live here are not too far from school. Educational is connected with Entertainment, for kids' fun, and with Common, for the quiet of it.

All the three segments are divided the same way, so that inside the torus all residents enjoy diversity. Thus, the three residential segments are divided into four neighborhoods, as shown in the following map.

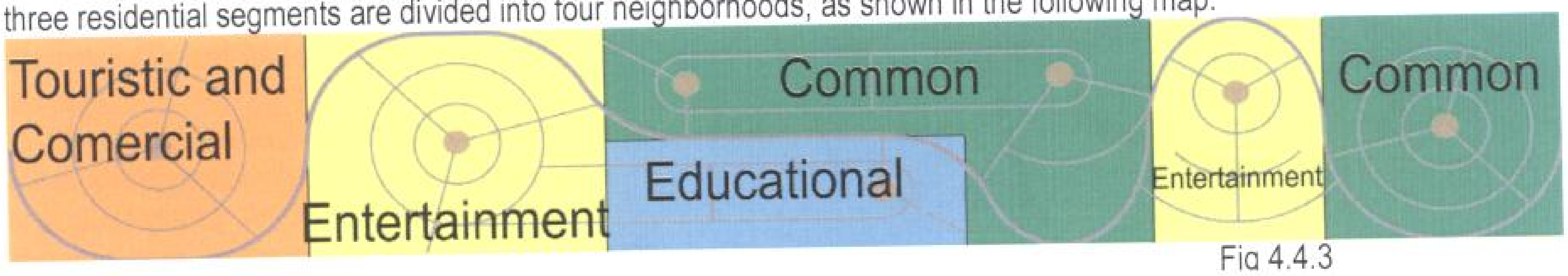


Fig 4.4.3

4.5 Entertainment

People benefit from a lot of facilities like those on Earth, such as stadiums, polyvalent buildings, restaurants, pubs, schools, etc. Besides normal hospitals, there is one more located in 0G where some operations can be done easier. Also, people who have burns on their bodies can float in 0G without making contact with beds and other things that cause more discomfort and pain. Not only physical health is important, but also psychical stability. Psychologists take care that people feel psychologically comfortable and make statistics about this thing.

People on Bellevistat have several entertainment activities. For a more familiar environment, we created amphitheatres that contain cinemas, theatres, musicals and shows. Due to a schedule, they can be watched in the same building. For example, when there is a play, or a musical, the screen on which the movie is watched can be removed so as not to trouble the actors that perform in a play. These activities educate people in a relaxant way. Furthermore, people can socialize after these events. People also benefit from parks, relaxing centers and shops. To enjoy all the advantages that Bellevistat offers, including zones with low gravity, we created two games which take place in 0G micro-sphere.

The first game is the equivalent of "Polo" on Earth. However, the game is played here without water, using more balls for conserving the impulse. It is played in 2 or more people. You must throw the ball from your arms so that you can move and achieve another one. The purpose is not to be hit of the opponent and not to remain isolated, without balls that help you to move.

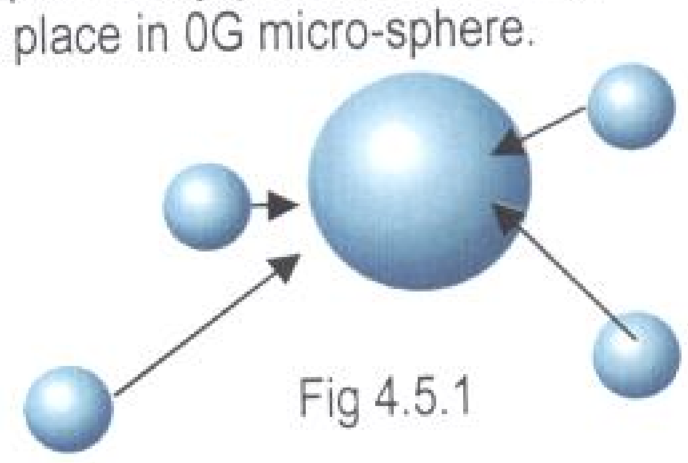


Fig 4.5.1

It is known that the water in 0G takes the form of the bubbles. The second game, "Bubble", is played between 2 teams. The players from each team have to bring as much water bubbles as possible at the team's central bubble. The team that collects the biggest amount of water wins.

One of the most important facilities is the room on the central axis, from which the residents can directly observe the outer space.

People also benefit from one of the two agricultural segments at the residential segments' edges, the "Belle view" areas.

„Labyrinth" comes from the Greek word „labrys", meaning double-bladed axis, symbol of the royal power, which is connected with the myth of Minos, Crete's king. The particularity of the segment "Belle Labrys" is a park with paths and plants that form a labyrinth. The residents can enter the labyrinth and travel through the ride. There are some repose places, benches, floral and decorative arrangements, a mini zoo, to make the ride more attractive.

"Forest" means „Silva" in Latin, this is why one of the segments is called „Belle Silva". It contains a forest where people can relax, have a walk, think about different things in a pleasant environment. It is a great place for the ones that love wild nature.

"Farm" means "Villa" in Latin and it is the characteristic of the "Belle Villa" segment. Here people have gardens and plots where they can grow diverse plants, for their own pleasure and utility.
Also here are small animals which make the environment more like the Earth one.

5. Automation

Bellevistat is a space station that needs cutting-edge technology in order to perform all operations successfully. The station needs automated systems both in the construction phase and after that. This is why the station depends very much on a good design of automated systems.

5.1 Automation of construction process

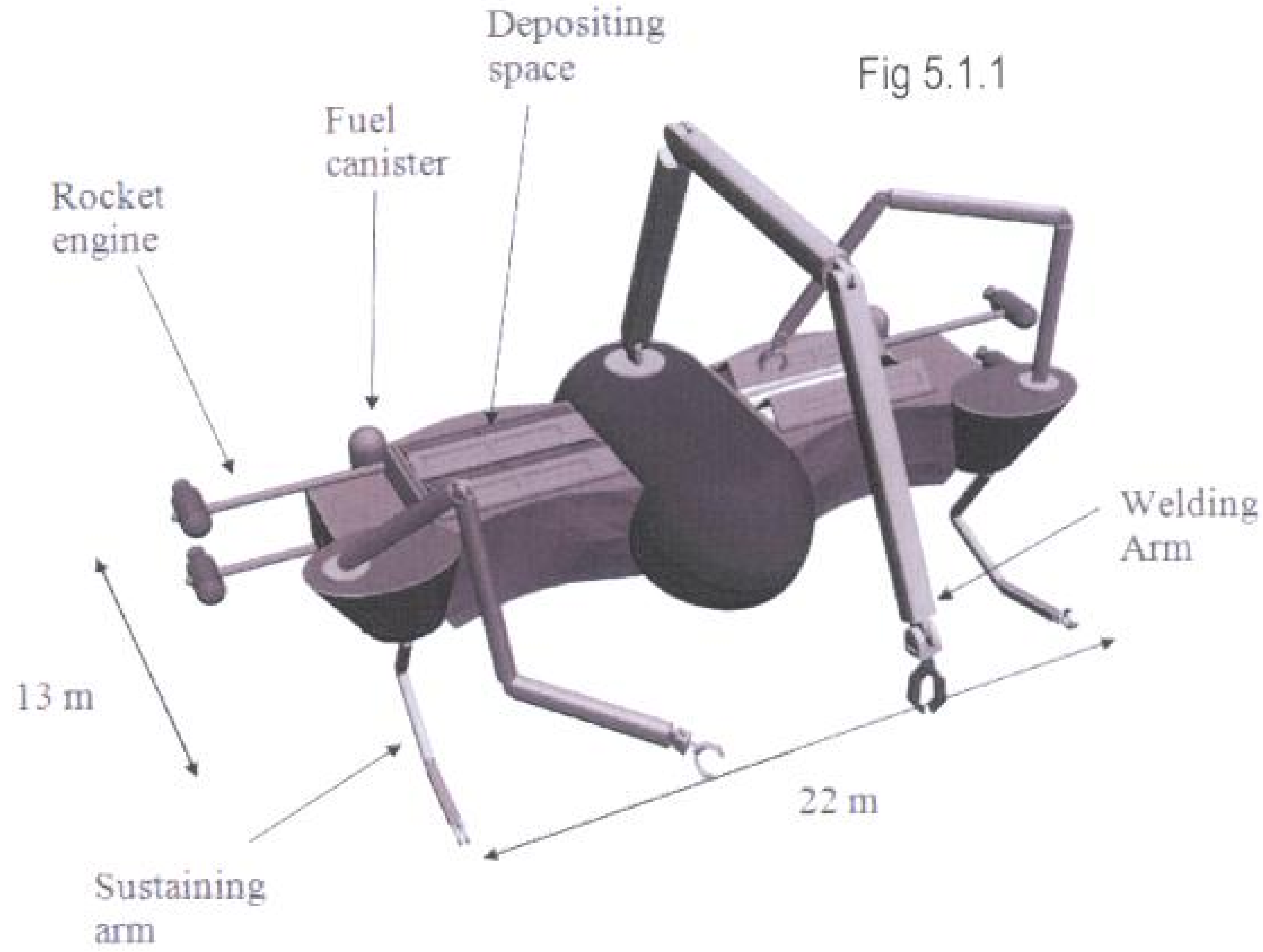


Fig 5.1.1

Bellevistat Space Station is constructed, consequent with 2.3, step by step, starting from the center to the exterior. The initial part (central part of Space Port C and central part of central cylinder unit and part of the central tube) is brought from Alexandriat (where it is also built), under contract with Foundation Society and transported from Libration point L5 to L4. Automated construction systems of Bellevistat do not interfere in this process.

After stabilizing this component in L4, FloatingArmDroid (Fig 5.1.1) robots begin to be brought in pieces through Space Port C, transported by Northdonning Hedweel Space Tugs. These robots are later assembled in a special space in the CCU. Hear, another special automated system, adaptable to the 4 different types of robots for construction assembles them. After a number of 4 FlotingArmDroids are operational, they begin the process of finishing SP C and CCU attached to it. Meantime, Space Tugs of Northdonning Hedweel continue to bring components for new construction robots.

Afterwards, 6 AdvancingRing robots, formerly assembled in the CCU begin the construction of horizontal tubes b1, b2, b3 and c1, c2, c3. After these tubes are finalized, FloatingArmDroid robots (already 21) begin functioning, starting the construction of the three torus segments (7 for each segment).

After finalizing the structure of components mentioned above, 3 AdvancingRing begin constructing circular tubes d1, d2 d3, each starting from one torus segment and ending at another. Also, other 3 AdvancingRing build the central part of tubes a1, a2 and a3, each assisted by 2 FloatingArmDroid, for building their exterior structure. A 7th AdvancingRing finishes central tube e. After finalizing the tubes, 8 FloatingArmDroids head towards the intersection between tubes a1, a2 and a3, building Space Ports A and B. Other 6 build the Central Industrial Zone, 2 the 0G Outpost and 12 the Industrial Mirror and Space Port.

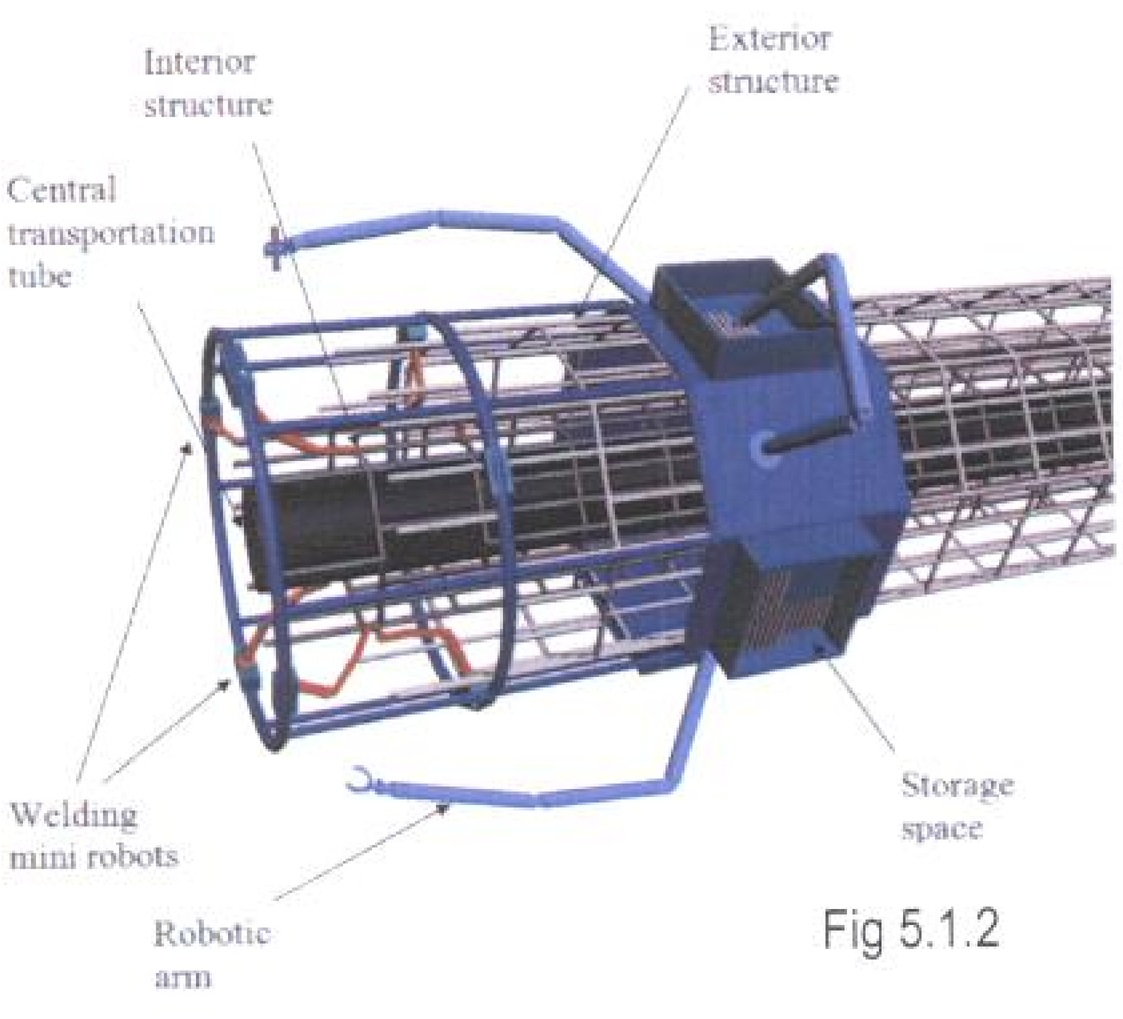


Fig 5.1.2

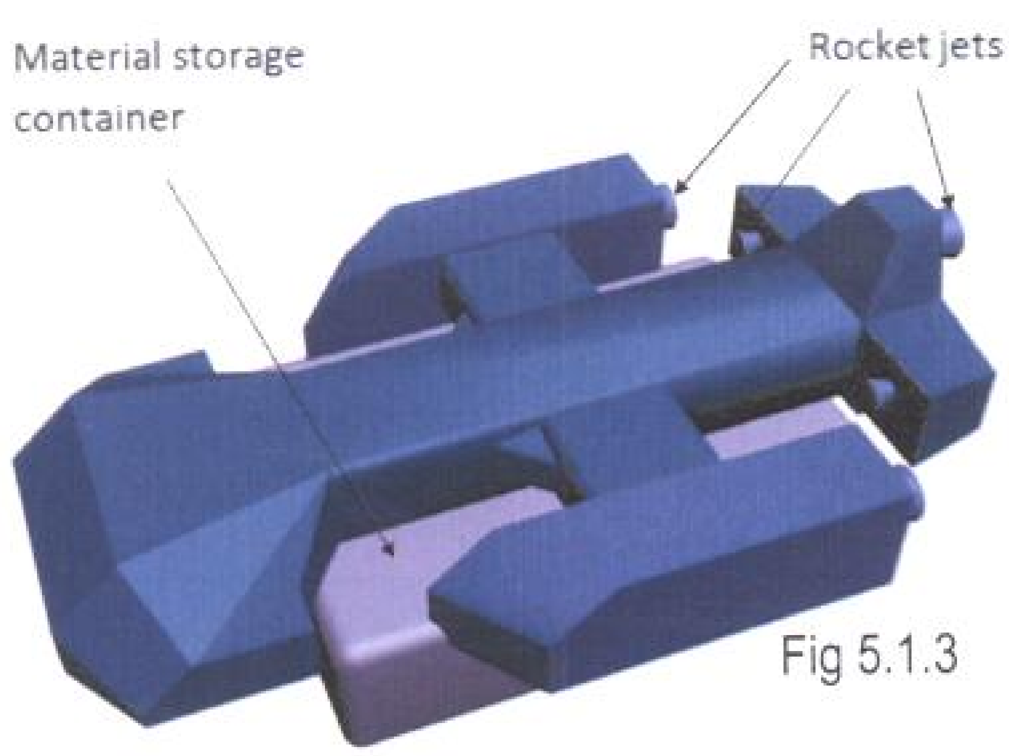


Fig 5.1.3

The entire process described above is done automatically, each robot having a virtual 3D map of the final station and its resistance structure. Also, they memorize stages that need to be followed and repetitive maneuvers. However, people supervise their activity from a special computerized centre in CCU. People communicate with robots through computers and radio waves. They may stop any robot at any time from the construction process, or interfere in its program and/or maneuvers.

We next describe robots required in construction and also their operation mode:

FloatingArmDroid (Fig 5.1.1)

A robot capable of traveling through void, helped by its' propulsion rockets with liquid oxygen and hydrogen. Besides these engines, it has other two maneuver arms and two smaller arms for fastening on the already built resistance structure. A fifth arm, situated centrally has a thermal welding device, for biding the resistance structure components placed by the other two maneuver arms. Components are deposited in two lateral special compartments, periodically refilled by other automated ships, the FastTranspShip described bellow.

AdvancingRing (Fig 5.1.2)

A special Robot conceived for building tubes step by step. It always uses the end of the tube it has already built, surrounding it. In front, the robot has two rings, and on each there are other 4 small robots, each equipped with a robotic arm for thermal welding. These robots can travel on the ring, which provides them access from different angles and positions to the resistance structure components that they are welding. The base part of the robot is represented by a continuous surface, with octagonal shape (the shape of the tube). This surface has 4 maneuver robotic arms and 4 depositing spaces for components, symmetrically distributed. Similar to the FloatingArmDroid, the robotic arms move and position different components, which are later welded by the small robots that move on the 2 rings. The 4 depositing spaces are also periodically refilled by FastTranspShips.

After finishing each part of the tube (constructed in front of the robot), the robot advances further, until the new end of the tube (using some wheels for rails whit brakes), from where it will begin building another part.

FastTranspShip(Fig 5.1.3)

An automated ship, with relatively low dimensions, with space for materials, rocket jets for movement and positioning and with a radio communication and detection system. This system is used for locating and synchronizing with the robot that needs to be refilled with construction materials (FloatingArmDroid or AdvancingRing).

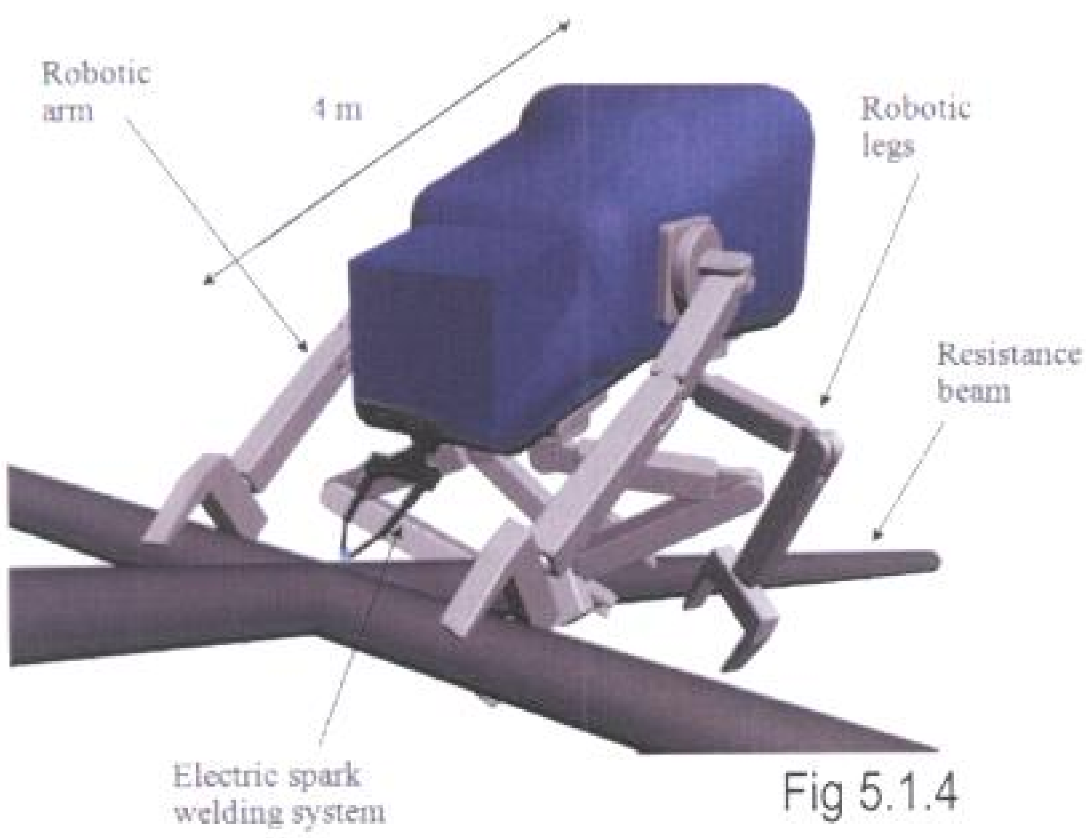


Fig 5.1.4

SpiderBuilder(Fig 5.1.4)

A robot with four mechanical legs with claws for seizing and fastening from the resistance structure. It also has an electrical arc welding device in front, and 2 mechanical arms for maneuvering different components (components that are transported on the upper part). The purpose of this robot is to build the interior of every component (the resistance and outer structure was previously built by the other robots). Also, it can reinforce the already built resistance structure by electric arc welding.

Name of Robot	Purpose	Number
FloatingArmDroid	Construction of major components	30
AdvancingRing	Construction of tubes	7
FastTranspShip	Transportation of materials	20
SpiderBuilder	Exterior and interior structure	300

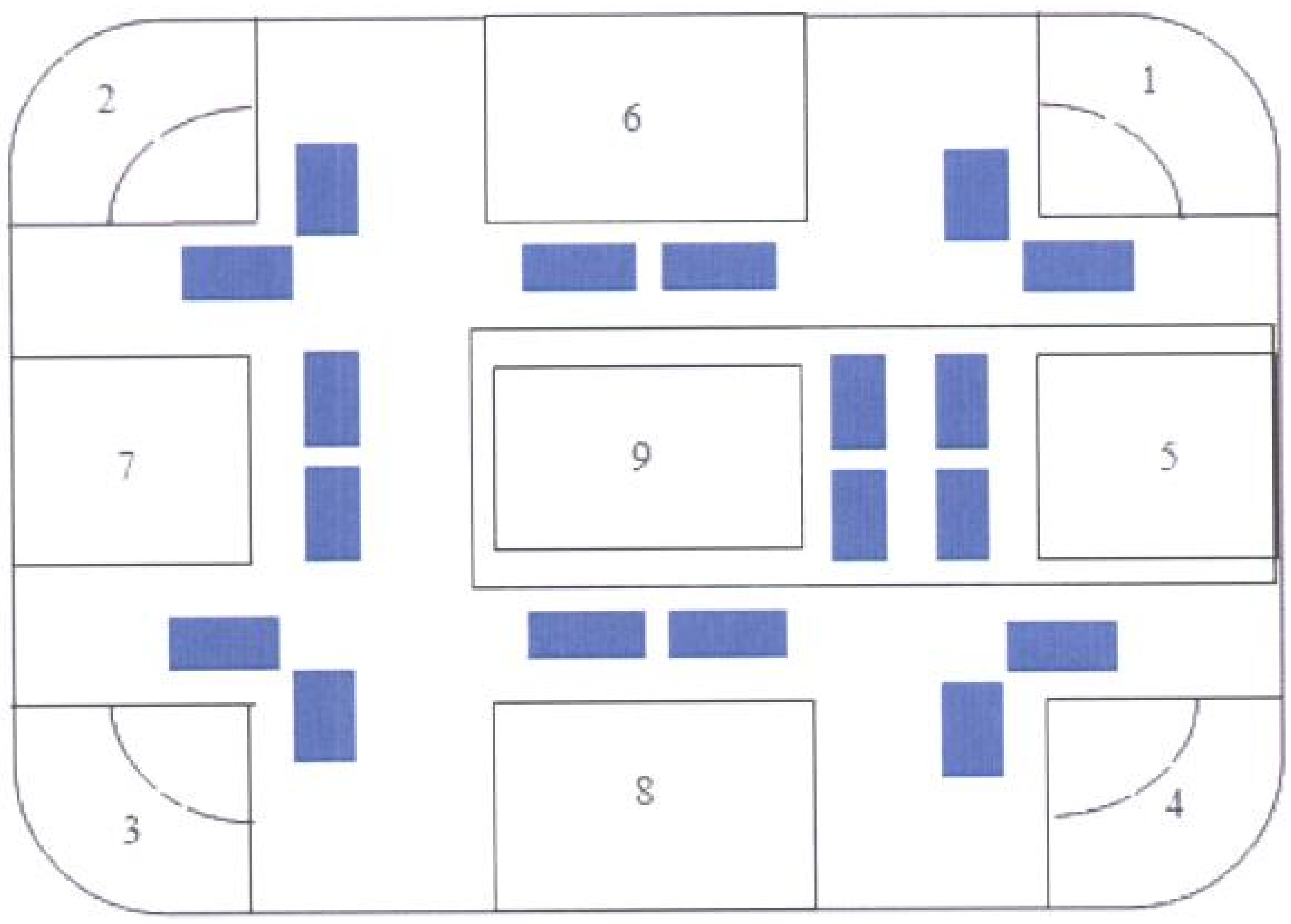
The total number of robots exceeds the total number needed for each type of robot, in order to ensure the efficiency of construction in case of malfunctions.

After finalizing the station, the construction robots described above are transported in the industrial mirror, for future industrial activities.

5.2 Facility Automation

Fig 5.2.1

Common robotic body – upper view



1, 2, 3, 4 – Space for movement components

5 –Navigation & recharging system

6, 7, 8 – space for other comp

9 – Central computer

Blue parts – fuel cells

A large part of the robots required for Bellevistat's operations will be based on the GPRB (General purpose robotic body).

Fig 5.2.1 describes the overall interior of a robotic body. The idea is to provide an adaptable body, with spaces for different attachable components that are added according to needs, components that help the robot accomplish a variety of tasks. As the body is modular only damaged components will need to be replaced in case of malfunctioning. This robotic body serves as the central component for robots accomplishing the following tasks: interior maintenance and repair, exterior fissure repair, exterior maintenance, asteroid material harvesting and interior finishing of homes. Some of the robots have a box placed above the central computer (9) which holds materials needed for fulfilling their tasks. The box can have another 2 jet engines + 2 fuel tanks attached in order to carry heavy charges. The robots come in three dimensions depending on the task they are designed for:

Small – 40 centimeters long and 28 centimeters wide
Medium – 1 meter long and 0.7 meters wide
Large – 2 meters long and 1.4 meters wide

In order to achieve this, the empty spaces (1 to 4 and 6 to 9) indicated on the figure can serve as support for a variety of components, in the way described by the table below:

Purpose	Movement components	Tool Component
Putting out fires	Legs or wheels	CO2 fuel tank in the middle,CO2 fire extinguisher arm, Arm
Floor cleaning	Wheels	Spinning brush, Broom + Dustpan
Exterior maintenance	2 jet engines, 2 electromagnetic clawed legs	1 arm, repair kit arm (screwdriver, auger etc.), solar panel cleaning brush, solar flare protection
Fissure repairing	4 electromagnetic clawed legs	2 arms, 1 panel replacing kit arm
Interior finishing	Described in section 5.4	
Mining	Described in section 5.5	

Of course combining tools with movement components make this kind of robots right for most of Bellevsitat's automation tasks as it covers a wide variety of jobs. The robots that don't use the GPRB are listed below:

Other	Description
Robots used for constructing the settlement	Described in section 5.1
Robots used in industry	Common industrial robots
Robots used for building other robots	Automated construction line
Water Management / Exterior repairs	Nanobots

Solar Flare Protection:

Robots working outside the settlement need solar flare protection. In order to achieve that the electronic components of the robots are radiation hardened. Radiation hardened chips are used for protecting the Mars Rover from radiations. Others computers such as System/4 Pi produced by IBM and used in the Space Shuttle use the same technique to protect from solar flares.

Contingency plans for failures:

Failure scenarios:

- Fissure:

For this type of emergencies, each zone (including both inside and outside of the torus) has some fissure repairing robots (described above) which will take care of repairs and replaces of the fissured materials. Robots on the inside move through electromagnetic clawed legs, while the robots on the exterior use a rail system. Because team work always has the greatest results the robots will communicate between each other using the wireless connection to the space station's network. From the combined backup obtained from different types of sensors the robots will be able to update the map of the settlement with high precision so they will know things like weather a complete replace is needed or just a reinforcement is enough. This will also help them synchronize very well. For example when one robot drags the fissured solar panel and the other replaces it with another one.

- Fire

Fire Robots will be used in order to stop the fires and to prevent new ones from happening. The robots use CO2 instead of water because water is a more important resource and is not to be wasted. Robots detect inflammable objects nearby and remove them using the robotic arm. The fire robots are stored in special places in the underground, near the cable network. When they are needed they just go under a point in the proximity of the fire and then rise to the surface through a hole covered with an electric door that automatically opens when a robot wants to pass.

Physical location of computers

Servers are widely separated to prevent local problems from affecting the whole system. This way if something like a fire takes place only few servers are affected by the incident. The others are capable of holding all the connections alive at a slightly reduced speed until the problem is solved. The servers are held in the central zone, but in different locations of it. Redundancy is very important if one targets reliability. This means every piece of information a server holds is also held on other 2 computers. The distance between computers holding same information is at least 100 meters. Servers support many request and therefore need a way to keep the temperature on normal values. This is why the servers are cooled with liquid nitrogen. The liquid nitrogen has a temperature below -196°C and has the added advantages of being non-toxic and non-combustible. The liquid nitrogen will eventually evaporate so the tanks are refilled from time to time to keep that from happening.

Security

In order to achieve a complete computerized system three aspects must be taken into consideration: security, usability and cost. In this case the security has to be as hard to bypass as possible, so the other two factors won't be taken too much into consideration. However the priority of the usability and cost grows with the decrease of the protected information's or object's importance. We will divide the security needs into three categories:

- low security needs: usability is the most important here so a simple voice scan is the best option (one method of the ones presented below)
- medium security needs: for e-mail address protection, protecting data about one's medical record, privacy for personal data, entering a house.(two of the three methods presented below)
- high security needs: for the most important operations on the settlement, operations that could easily destroy the whole station, NOBODY has full access. Full access can only be obtained by combining the permissions of a number of persons (all the three methods presented below are used).

Each of these persons has to authenticate themselves to be able to use his permissions. The authentication consists of a classic three-factor authentication. This means you must pass three different methods of authentication.

One by one the computer checks the following:

1. "something you know": This means a password only you know
2. "something you have": A magnetic key identifying you is required
3. "something you are": This last method consists of biometrics; In other words your voice print and your retina are scanned.

The identity of anybody who passed the 3 steps is known by the computer, which now also knows what commands he is authorized to use. In the case of successive tries to execute a forbidden command all user's rights are temporarily blocked. The accounts can be unlocked only by another person that has the right to give your permissions back.

From time to time audits will be performed in order to check if everyone followed the security policy. Also from time to time the security administrators will try to hack into the system so that every potential security hole will be filled before being attacked by real hackers.

Even with all the protection, physical security comes first. It's useless to use unbreakable passwords if we don't assure physical security. So every important server is guarded by robots and it's looked after all the time.

5.3 Habitability and community automation

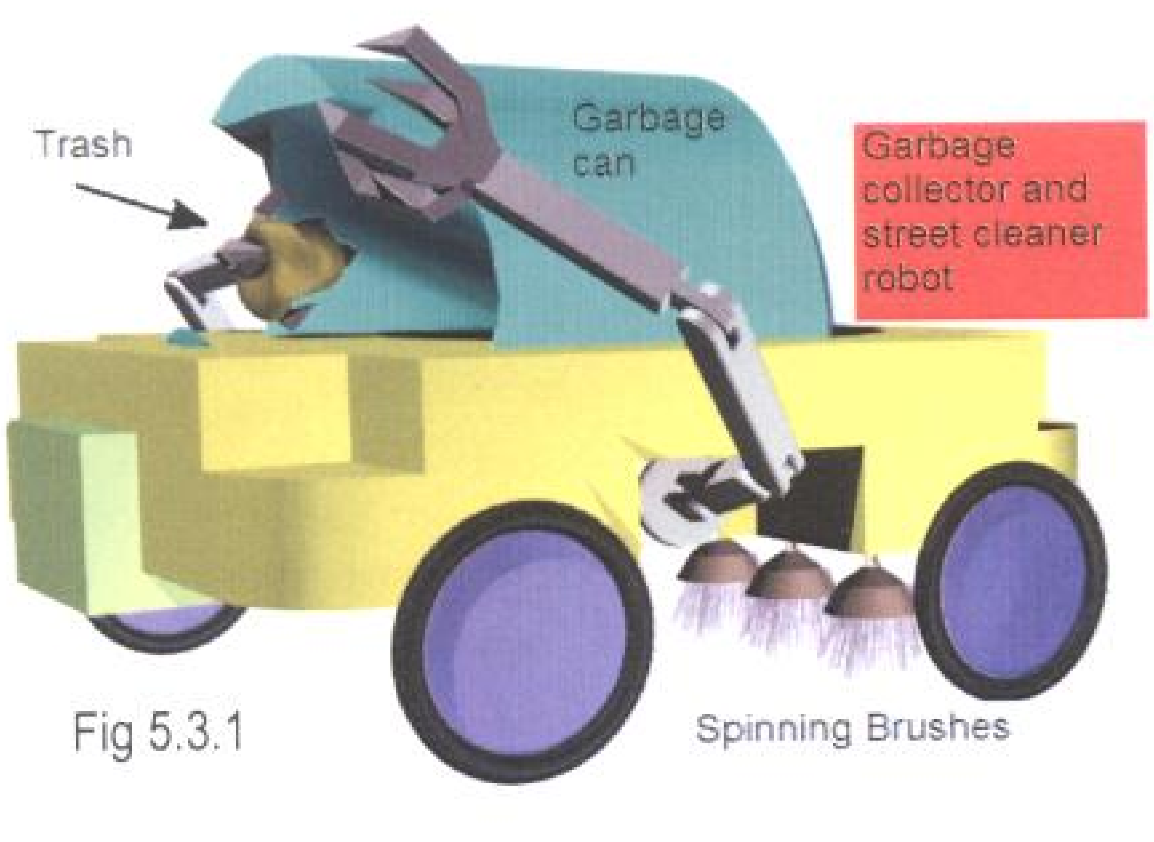


Fig 5.3.1

To improve life's quality, productivity and comfort on Bellevistat it is necessary to have an efficient automated system capable of performing all needed functions, which can replace the inhabitants' manual labor. Because of maintenance reasons and the necessity of a clean, healthy atmosphere, all Bellevistat houses are provided with a robot, specialized in house holding operations. The Cleaner robot is a multifunctional one, which takes care of all the work in the house; among its functions being included:

- Dust removal, air filtration (eliminates pathogenic agents from the air);
- Fixing and surface cleaning (sweeping, washing, polishing, etc.) including the upper parts of the house;
- Moving objects;

The robot's design was chosen in order to provide high mobility (so that it doesn't discomfort the inhabitants) and for maximum efficiency. It's made of a Fe-Ni alloy that provides specific resistance to shocks and it is anticorrosive. Its structure is mainly composed of the main body, which has inside tools, storage space, rechargeable fuel cells and the central computer that controls its functions.

The Cleaner has mobile, extensible arms, which can perform a variety of operations due to the possibility of changing the tool from the terminal point of the arms.

The tools are: broom, dust pan, brush (one attachable and one underneath), dryer, sponge, duster, scrapple, etc.

The robot has four compartments for keeping the tools, located in the marginal parts of its body, while in the center it has the main computer. The other storage compartments (for cleaning substances, water and garbage) are placed in the lateral parts. Under the main body the robot has a rotating brush, which cleans while the robot is moving, making it more efficient in cleaning the extended surfaces. Because the arms are extensible it can easily reach the upper parts of the house.

The Cleaner also takes care of gardening and the exterior of the house. It is able to water the plants, to cut them, to pick the vegetables and fruits and store them in one of its compartments. And to perform these actions, as auxiliary tools, it has a pincer and a hose. The robot is based on the small version of the GPRB (see section 5.2) which means it is 40 centimeters long and 28 centimeters wide.

As most of the robots are GPRB-based, they look almost similar. Fig 5.3.1 illustrates the garbage collector and street cleaner robot used to maintain the fairness on Bellevistat's environment

Other automated systems

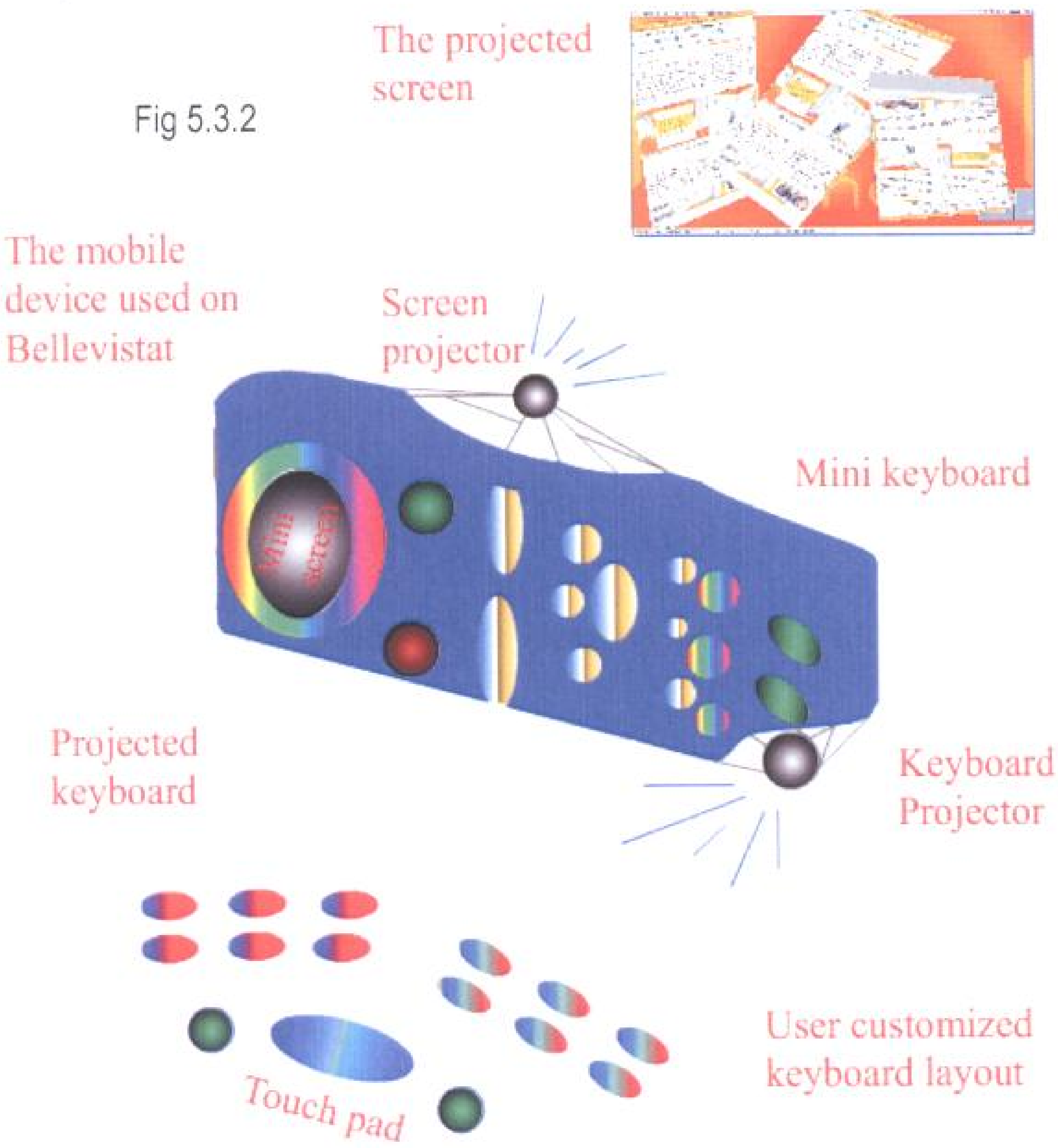
One of the facilities on the settlement is the Delivery System (DelSys). It consists of an underground rails network, which are used by GPRB-based robots that carry a package to its destination. All the houses on Bellevistat are connected to the delivery facility. The system is used for food ordering, but also for online shopping. When an inhabitant or a tourist logs into the online store software he is recognized by the computer and the bill is paid from its card. He can then choose what he would like to receive and then send the request to the server, which sends one or more robots to deliver the command.

In agriculture there are special automated animal folds, which are provided with specific systems that replace manual labor and facilitate life conditions for the animals. To maintain the hygiene and to collect the organic matter there is an air suction system. Apart from this there is a specific area for medical tests and other care operations. In this area there is a robotic system with arms, with high mobility that can shear the animal (sheep, goats), brush (rabbits), collect eggs, etc. Another system is being used for milking. A main computer collects the data about the animal and controls the periodical vaccination of the animal.

The fold is provided with light because light is one important factor for animal growth.

Computers on Bellevistat

Fig 5.3.2



Computers tend to become more and more important in our lives. We spend more and more time in front of the computer display. In 2028 they will probably be indispensable. On Bellevistat mobile phones are genuine personal computers. They connect to the wireless computer network or to Earth's internet giving the inhabitants the ability to communicate with other people living on the settlement, exchange files or even play video games with them. The devices can project the screen on a wall and the keyboard on a table. This allows the keyboard to be customized by the user, allows it to be multi-layered, to have certain configurations (for games, for typing) and also makes the projection of huge screens possible. When the settlements inhabitants are home they can use a usual computer and a usual keyboard as most of the people prefer having a mechanic feedback when pressing a key. You can see the mobile device in the fig 5.3.2.

Personal data can be stored on the personal computer or on the mobile device and can be accessed only after passing two authentication steps. One needs to type a password and get his finger scanned in order to obtain the finger print. If the two belong to the person that owns the files then you can access them. The owner is also able to control its robots by vocal command. This way the robot first checks if the voice is his owner's and then executes the received command.

It's very hard to estimate the bandwidth requirements to enable computer connectivity in 20 years. Nobody knows how things will evolve and how much technology will advance. Many people claim that Bill Gates has made this statement in 1981:"640K ought to be enough for anybody." It's no need to say that if he really said that he was miles away from the truth. So even if he is the man who made the largest amount of money out of computers, he still can't approximate further needs. Still, based on the fact that the bandwidth grows exponential, growing by 40% to 100% every year we can estimate the required bandwidth on Bellevistat:

Connection	Bandwidth
Internal	512 Terrabits per second
External	16 Terrabits per second

Bellevistat's network diagram is show in fig 5.3.3.

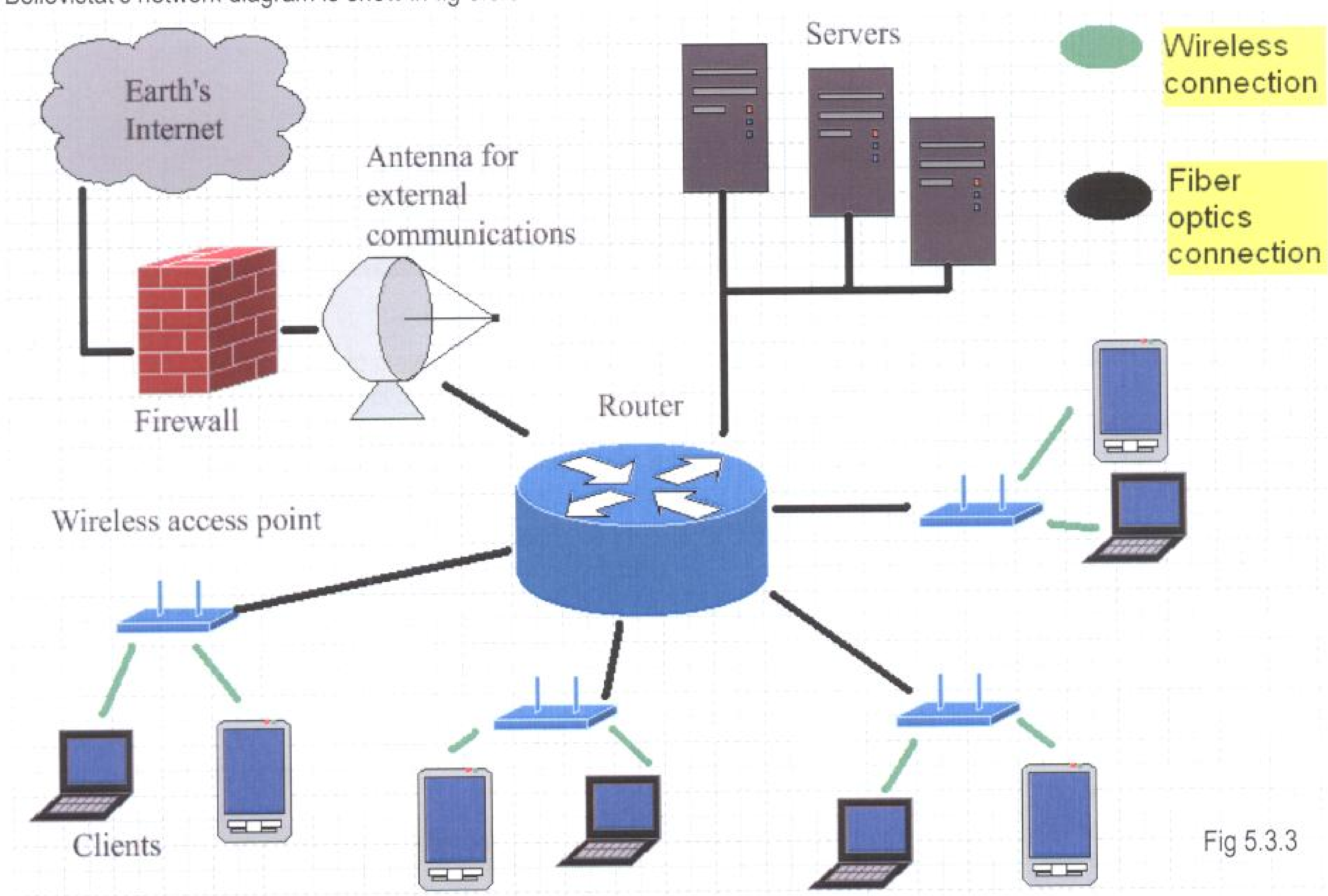


Fig 5.3.3

5.4 Interior finishing

For interior finishing GPRB-based robots are used. Every building has a number of different robots working on it. They synchronize with each other through the wireless connection to the settlement's network so that they are able to work simultaneously in order to reduce the construction time.

The water tubes system, the delivery system and the wires are all placed underground. Robots assemble the pipes, spread the wires and make sure they reach all the important places in the house. Robots then connect the pipes and the wires from the house to the underground network. As the pipes are not very esthetic they are covered with a thin cermet mask.

The floors are built of more parts, just like a puzzle. Once the house is connected to all the facilities and the cermet has set, another robot, equipped with a repair kit arm, installs the floor pieces. The kitchen and the bathrooms have the floor covered with brownstones while the other rooms have it covered with parquet.

The other floors (if the house/building has more than one level) are installed in the same way. When the floor is finished, the robot can climb the stairs in order to do the same thing for the upper floors.

Now another robot comes and paints the walls by using an airless spray gun. The main advantage of the airless spray gun is that it can cover extremely large surfaces in a short time. When the paint has dried maintenance robots like the floor cleaning robot (section 5.2) cleans the house. Now the house is ready to be decorated so the last robot comes and places the furniture. As the furniture is modular and light the robot easily assembles it and places it in the right spot. By now the house is fully functional and ready to meet its owners.

The time estimated to complete the interior of a common house is about 32 hours adding another 12 hours with each extra floor. Most of the time is spent waiting for the concrete and the paint to dry. Meanwhile the robots can finish the interior of other houses.

Fig 5.4.1 Illustrates two robots finishing the interior of a building.

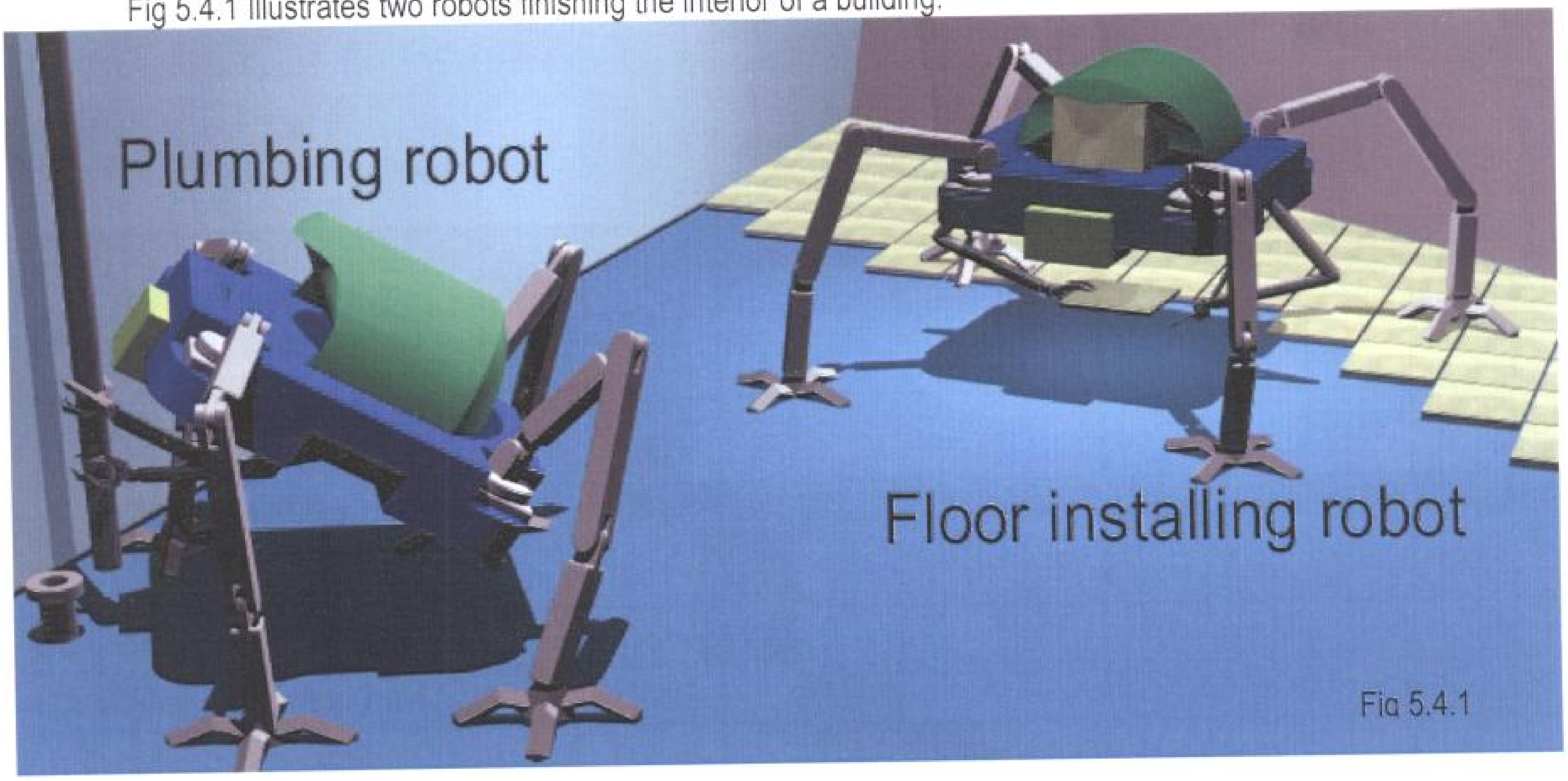


Fig 5.4.1

5.5 Asteroid Mining

For harvesting asteroid materials, an automated type of robot is used. This robot (the Harvester) is based on the common robotic body, described at 5.2.

This robot has legs (one in each space from 1 to 4), equipped with special clamping systems, in order to ensure contact with the asteroid surface during work (because the asteroid generates almost no gravitational force). In order to successfully fix the four legs in the "soil" at the beginning, the robot uses its jets orientated upwards. Then, for movement, it removes one leg at a time, using the other three as a support when reintroducing the fourth.

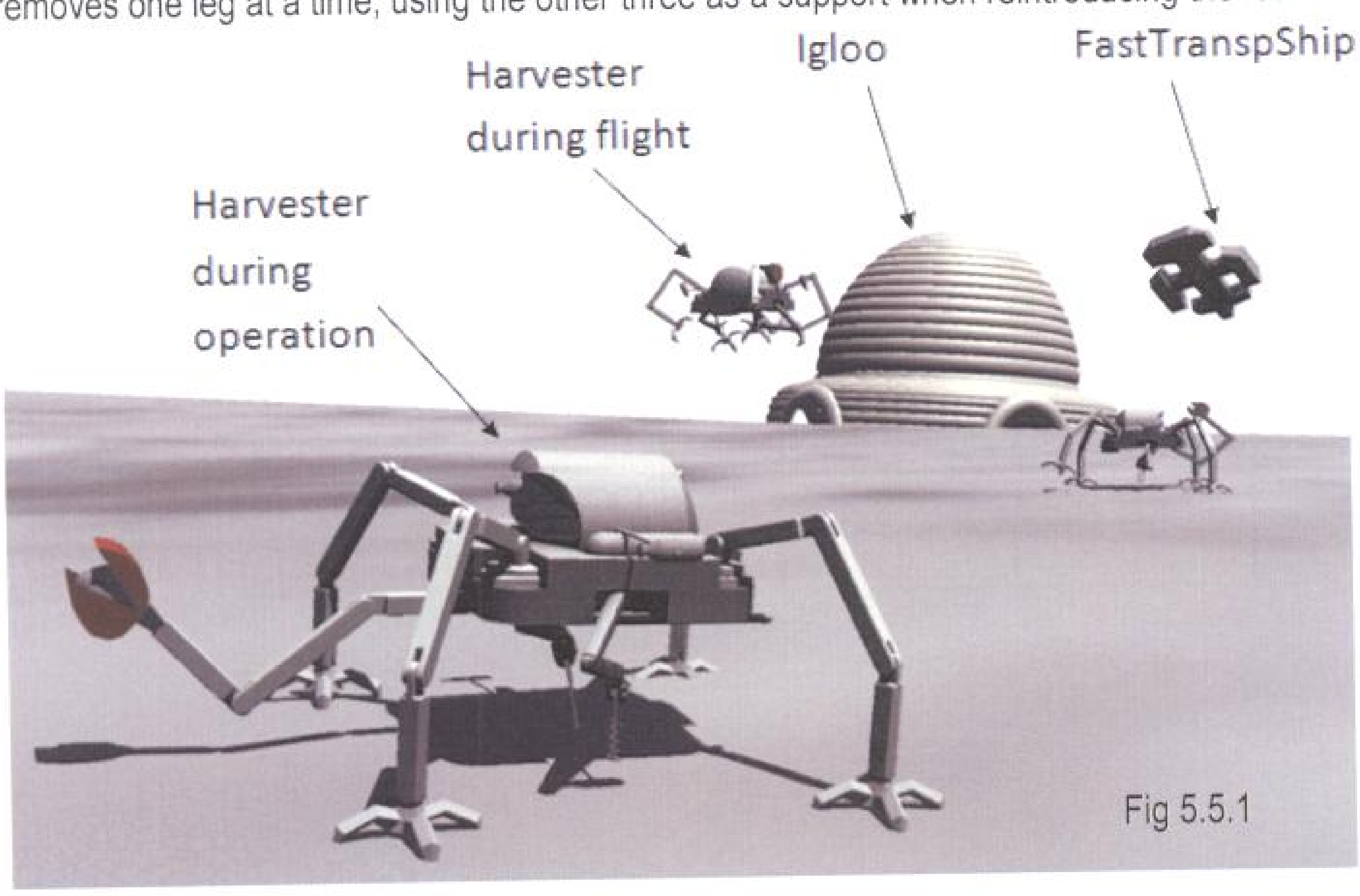


Fig 5.5.1

Space 7 of the common robotic body serves as a support for an excavating robotic arm, for grabbing materials displaced before and introducing them in the storage space above. Space 6 is equipped with a drilling robotic arm, and space 8 with a jackhammer robotic arm, with the purpose of displacing material from the asteroid surface below.

This robot is also equipped with a temporary storage volume above, for depositing asteroid materials and with rockets and fuel containers on both its sides. These rockets are also controlled by the central computer.

The harvester periodically returns to its utility warehouse ore igloo, as described at 2.4. The robot leaves its cargo inside and if necessary, recharges its fuel cells (through the electrical recharging system near the navigation system) and/or changes its fuel containers for its rocket jets. There is one human supervisor at each 3 or four Harvesters (one human supervisor for each Igloo). From time to time, the materials are transported from the igloo to the central refining factory by the electrical vehicles also mentioned at 2.4 (the MovingPill).

The entire mining factory has a FastTranspShip at its disposal, similar to that described at 5.1. In this case, the automated ship has the purpose of "rescuing" harvesters that are in difficulty or damaged on the asteroid, and return them to the robot maintenance space near the central refining factory. Additionally, the FastTranspShip may move one Harvester from one place of the asteroid to another, when the distance is significant (for example when Harvesters are moved from one Igloo to another, when resources in one area are depleted). The FastTranspShip also circles the asteroid periodically, scanning its surface in search for new areas with resources.

6.0 Schedule and Cost

6.1 Design Construction schedule

	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Contract awarded	■										
Final design, planning and approval	■	■									
Ferro-nickel asteroid placement in orbit		■									
Asteroid mining		■	■	■	■	■	■	■	■	■	■
CCU and CSP C arrival and completion			■								
Main construction crew arrival			■								
Deploying the Central Tube				■							
Construction of Spokes				■	■						
Torus segments construction					■	■	■				
Circumferential tubes and arms construction							■				
Deployment of SCL and PT							■	■			
SP A and B construction							■	■			
CIZ construction								■			
0g Outpost and Mirror construction								■	■		
Rotating the settlement									■		
Interior finishing of torus segments									■		
Pressurizing torus segments									■		
Final testing									■	■	
Inhabitants ships launch										■	
Inhabitants arrival											■
Settlement begins operating											■

6.2 Construction cost

Item	Quantity	Cost	Total Cost
Design and planning			
Architects and engineers	2000 (2 years)	150,000	600,000,000
Project managers	1000(11 years)	200,000	2,200,000,000
Central part construction, delivering and finishing			0
Construction crew	40(1 years)	500,000	20,000,000
Construction equipment	-	400,000	400,000
Ferro-Nickel materials	1,888,363,592 kg	130	245,487,266,000
FloatingArm Droid	4	150,000	600,000
Fiberglass	2,331,313,076 kg	300	699,393,922,000
Kevlar	1,311,363,605 kg	1050	1,376,931,785,000
Polyethylene HIWH	2,039,898,942 kg	1010	2,060,297,931,000
Spokes construction			0
Construction crew	50(2 years)	500,000	50,000,000
Ferro-Nickel materials	1,465,741,468 kg	80	117,259,317,000
AdvancingRing robot	6	140,000	840,000
FastTransShip	6	200,000	1,200,000
Construction equipment	-	750,000	750,000
Torus segments			0
Construction crew	750(3 years)	350,000	787,500,000
Construction equipment	-	1,000,000	1,000,000
Ferro-Nickel materials	8,058,334,601 kg	80	644,666,768,000
Fiberglass	9,948,561,236 kg	120	1,193,827,348,000
Polystyrene	2,611,497,325 kg	1010	2,637,612,298,000
Polyethylene HIWH	8,704,911,082 kg	1010	8,791,960,192,000
Kevlar	5,596,065,695 kg	1050	5,875,868,979,000
Lead	1,410,208,552 kg	1100	1,551,229,407,000
Ammonia	1,436,880,206 kg	1050	1,508,724,217,000
- Nitrogen - Hydrogen	1,183,313,111 kg 253,567,095 kg		0
Oxygen	364,096,342 kg	1050	382,301,160,000
Carbon dioxide	715,190 kg	1050	750,949,000
Other gases	21,022,230 kg	1050	22,073,342,000
Carbon compounds	2,215,000 kg	1100	2,436,500,000
FloatingArmDroid	21	150,000	3,150,000
FastTranspShip	10(+4)	200,000	800,000
Peripherical tube, arms, central tube and solar cell layer			0
Construction crew	100(2 years)	350,000	70,000,000
Construction equipment	-	500,000	500,000
Ferro-Nickel materials	3,580,000,000 kg	80	286,400,000,000
Solar cells	10,000,000 m^2	40	400,000,000
AdvancingRing robot	7(+1)	140,000	140,000
FloatingArmDroid	6(+0)	150,000	0
FastTranspShip	12(+2)	200,000	400,000
Mirror, 0g Outpost, SpacePorts A and B and Central Zone			0
Construction crew	250(2 years)	350,000	175,000,000
Construction equipment	-	850,000	850,000
FloatingArmDroid	28(+7)	150,000	1,050,000
FastTranspShip	14(+2)	200,000	400,000
Ferro-nickel materials	1,374,132,627 kg	80	109,930,611,000
Polyethylene HIWH	148,440,252 kg	1050	155,862,265,000
Ammonia	38,243,960 kg	1050	40,156,158,000

-Nitrogen - Hydrogen	31,495,026 kg 6,748,935 kg		0
Oxygen	9,690,778 kg	1050	10,175,319,000
Carbon dioxide	19,036 kg	1050	19,988,000
Other gases	559,528 kg	1050	587,505,000
High reflective material	2,817,280 kg	1100	3,099,008,000
Interior finishing			0
Construction crew	500(1 year)	350,000	175,000,000
Construction equipment	-	5,000,000	5,000,000
Plumbing	-	25,000,000	25,000,000
Electricity	-	17,000,000	17,000,000
House building	6,500	19,000	123,500,000
Maintenance robots	8,000	8,500	68,000,000
People	18,000	100,000	1,800,000,000
Additional expenses	-	-	100,000,000
Total			27,720,880,615,000

7. Business development

7.1 Extraterrestrial material harvesting and refining

All our station' mining operations, and on spot processing are done by deploying industrial operations such as that described at section 2.4. We anticipate this as a very profitable feature of Bellevistat. If the refined material or other manufactured goods need to be transported to Earth's surface, they are encapsulated into a one way vehicle and launched to earth. The vehicle is spherical, and to the outside, acting as protection layer against friction on re-entering the atmosphere, there is a layer of composite material. It is made of asteroid dust and useless material, pressed tightly to form a higher density layer.

The vehicle is launched from one of our torus segment's ports, on a trajectory and with a velocity calculated so that the resultant trajectory is directly towards earth, and the relative velocity to earth is low.

As the "ball" re-enters the atmosphere it increases its velocity only slightly (energetical calculus of final velocity), so the "ball" can open parachutes and land smoothly at the desired spot (in the ocean). Once it has reached the surface of the ocean packed bags are filled with compressed and deployed from the point where the parachutes were attached. This is in order to keep it from going to the bottom of the ocean until it is recovered.

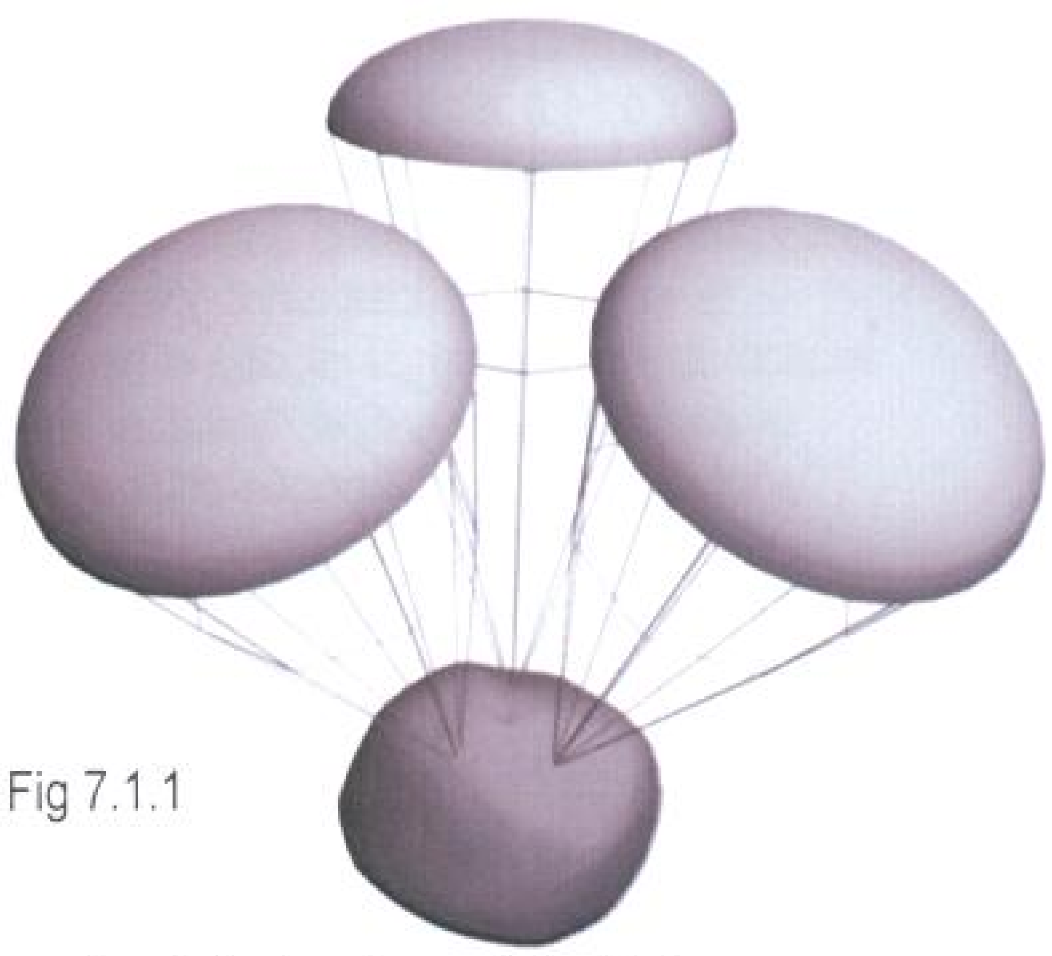


Fig 7.1.1

The ball is designed with engines that ensure the initial velocity and then detach. If something unpredictable should hit it and deviate it from its course, this will not be a big problem, as it does not have a high velocity and only the landing point will change.

7.2 Space manufacturing

Bellevistat is an important manufacturing point for any type of machinery needed for space exploration and exploitation. This means satellites, space ships of all sizes machinery needed for asteroid lunar or planetary exploitations and processing, and even other space settlement projects, or components. To this end we have a large dedicated area, the inside of the mirror at the end of the central tube. This acts as a large 600 meters in diameter manufacturing and launching site. It is placed conveniently in 0 and low gravity area and very far from human populated or other essential areas of the station.

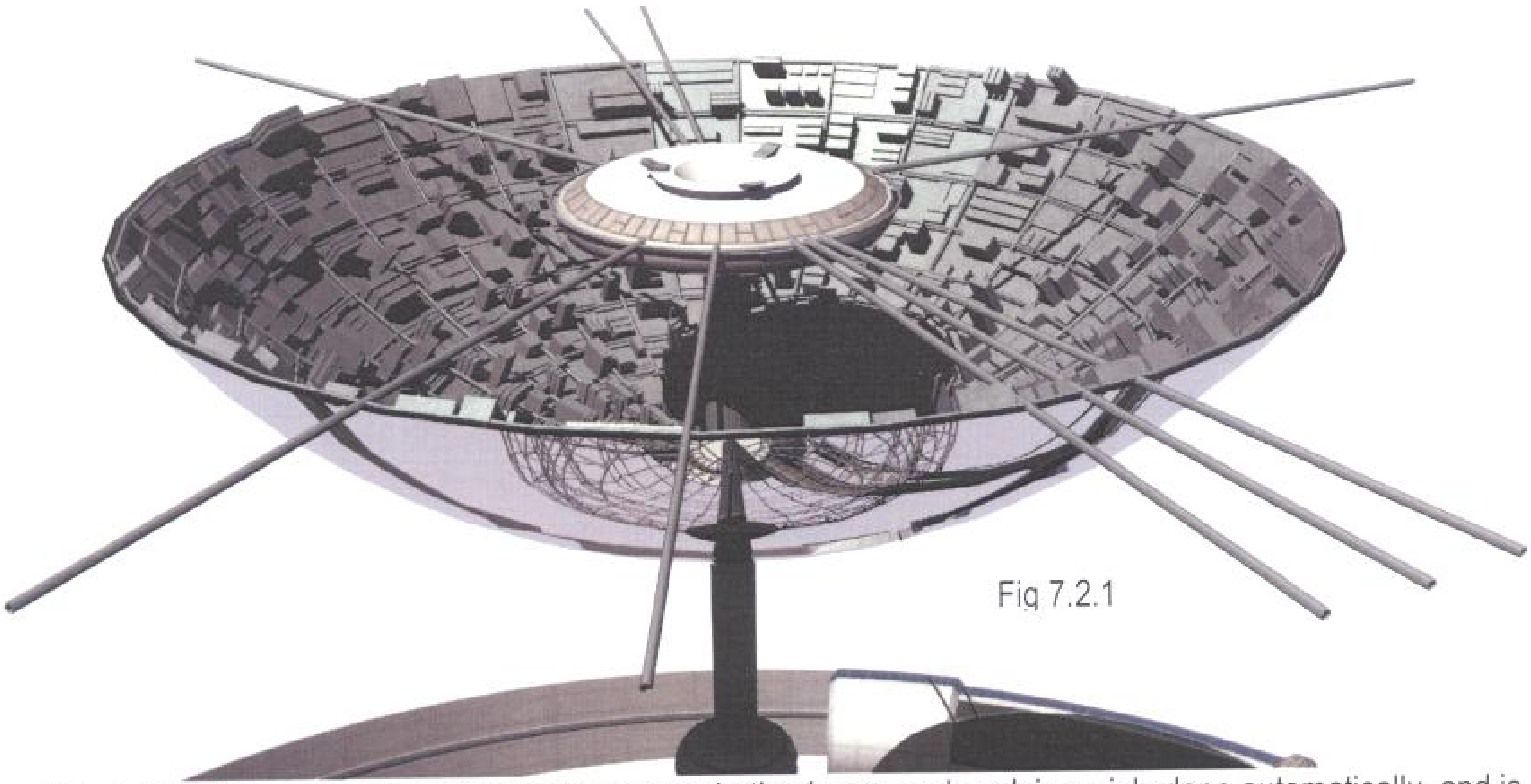


Fig 7.2.1

The inside of the mirror is equipped with many robotized arms and work is mainly done automatically, and is only supervised and directed from the central office area in the center cylindrical unit. Once the ship or piece of project is built it is either transported through the central tube to its destination on the station or it is launched from the port situated in the middle of the mirror. If something needs to be manufactured that exceeds the mirrors dimensions, there are tubes of 1m diameter that can be deployed to the necessary position in order to keep the machinery being build safely and firmly attached to the station, and also act as support points for floating armDroids and other machinery that is needed in the process o building. If needed, these tubes can extend to the necessary level of artificial gravity and the resulting project can take after Bellevistat's rotation movement.

7.3 Tourism

Another good source of profit for Bellevistat is tourism. An estimate of 1000 tourists is on the station at a given time. They are accommodated in specially designed hotels, taller than the normal houses, meant to offer a nice view of the whole torus section. On each torus section there is great thematic diversity (see section 4). The wide surfaces and big spaces, presented in sections 2.2 and 4 are meant to ensure a pleasant, open and welcoming environment, as much earth-like as possible. This impression is also conveyed by the wider spaces at one end of each torus section, which offer simulation of different natural environments from earth. Tourists are invited to take part in special 0g games and attractions (eg: space observations), and there is also one exhibit and commercial theme zone(section 4) where they can observe operations specific to the station such as industry, and how different systems work (eg: life-support, station's trajectory, mining operations etc.).

There are museums with samples of what is manufactured and used in industrial processes. Shops are the place where tourists can buy souvenirs, such as miniature models of the space station, all completely made from harmless by-products that cannot be reused.

Life is different on Bellevistat in many ways. Tourists will be intrigued to find out that even the things they took for granted on earth are a little different in space (artificial gravity for example). It will be a very interesting experience as a whole for every tourist visiting our station.

CHAPTER 8 - COMPLIANCE MATRIX

Chapter	Description	Page number
1.0 Basic requirements	- description of the design, development, construction of the Bellevistat space settlement community	1
	- tourist, commercial center	1
	- important role in space manufacturing in Earth orbit	1
2.0 Structural Design	-18,000 residents	1 – 11
	-1000 transient population	1 – 11
2.1 External Configuration	- drawings showing all volumes, their uses and dimensions	1, 3 – 4
	- construction materials	4
	- artificial gravity	2
	- low-gravity environment	2 – 4
	- protection from radiation and debris penetration	4
2.2 Internal Arrangement	- utilization of all interior areas	5 – 7
	- justification for facility sizes and locations	6 – 7
	- overall map of interior land areas showing their utilization	6
	- use of unpressurized and micro-gravity facilities	7
2.3 Construction Sequence	- process required to construct the settlement	7 – 8
	- drawings showing several intermediate steps of settlement assembly	7 – 8
2.4 Mining Facilities	- illustration of mining infrastructure on asteroid	9
	- typical mining operation description	9 – 10
	- illustration of asteroid relative position to Bellevistat	9
2.5 Docking Facilities	- exterior drawing showing widely separated port locations	10 – 11
	- docking procedures description and drawing	10 – 11
	- launching procedure	11
3.0 Operation and Infrastructure	- facilities and infrastructure necessary for operating the community	11 – 24
	- accommodating incoming and outgoing space vehicles	11 – 24
3.1 Construction Materials Sources	- identification of the orbit location and argumentation for the choice	11 – 12
	- sources of materials and equipment used in construction and operation	11 – 12
	- means for transporting materials to the Aresam location	11 – 12
	- storage between arrival and use	11 – 12
3.2 Community Infrastructure	- food production	12 – 15
	- electrical power generation and distribution	16
	- internal and external communication systems	17
	- internal transportation systems	17 – 18
	- atmosphere/climate/weather control	19
	- household and industrial solid waste management	20
	- water management	20 – 21
	- day/night cycle provision	21
3.3 Space Infrastructure	- identification of existing or new on-orbit infrastructure required to develop or sustain settlement operation	21 – 23
	- chart representing space infrastructure and vehicle requirements	21 – 22
	- commercial development and operations separated from this contract	21 – 22
3.4 Animals feed and facilities	- table describing animal facilities	23 – 24
	- drawing showing animal facilities	23
3.5 Material for interior design	- table identifiing materials and materials sources	24
4.0 Human Factors	-traditional community attributes	24
4.1 Community Design	-comfortable suburban environment	24 – 25
	-variety of consumables and other supplies	24 – 25
	-illustration depicting locations of amenities	25
4.2 Residential Design	-design of typical residential homes	25 – 26

Bibliography

1. *Space Settlements* – A Design Study. NASA SP-413, 1977 US Government Printing Office
2. *Space Resources and Space Settlements.* NASA SP-428, 1979 US Government Printing Office
3. *Mining the Sky - Untold Riches from the Asteroids, Comets, and Planets.* John S. Lewis, 1996 Addison-Wesley Publishing Company
4. *Spacecraft Systems Engineering.* Peter Fortescue / John Stark, 1995 John Wiley and Sons
5. *Elements of Spacecraft Design.* Charles D. Brown, 2002 American Institute of Aeronautics and Astronautics
6. *Solar Power Satellites.* Glaser/Davidson/Csigi, 1998 Wiley-Praxis
7. *Designing Places for People.* C. M. Deasy / Thomas E. Lasswell, 1985 Whitney Library of Design
8. *Humans and Automation: System Design and Research Issues.* Thomas B. Sheridan, 2002 John Wiley & Sons
9. *Project Management.* Harold Kerzner, 2003 John Wiley & Sons
10. *Asteroids - Their Nature and Utilization (Second Edition).* Charles T. Kowal, 1998 Wiley / Praxis
11. *The Space Environment - Implications for Spacecraft Design.* Alan C. Tribble, 2003 Princeton University Press
12. *Mainly heat, radiation and mechanics* – Richard P. Feynman
13. *Mechanics* - L. D. Landau, E. M. Lifshitz
14. *Living and Working in Space (Second Edition)* - Philip R. Harris, 1996 Wiley/Praxis
15. *Astronomie* - Mihail Sandu, Editura Didactica si Pedagogica, R.A. Bucuresti 2003

Web sites consulted

1. http://www.wikipedia.org
2. http://www.nas.nasa.gov/
3. http://www.space.com/
4. http://www.spaceset.org
5. http://www.hydroponics.com
6. http://science.howstuffworks.com
7. http://www.esa.int
8. http://www.nss.org/
9. http://www.bbc.co.uk/science/space/
10. http://www.chron.com/news/space/
11. http://www.spaceweather.com/
12. http://space.newscientist.com