International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 10 | October - 2022 Impact Factor: 7.185 ISSN: 2582-3930

ANALYSING THE REQUIREMENTS FOR A SPACE HABITAT

(Space Habitat Design Proposal)

Shubhi Bhatia

Student, Amity International School, Noida

Keywords: space, orbital settlement, Venus, artificial gravity, space resources

ABSTRACT

As overpopulation, global warming, and severe pollution begin to take a toll on earth, scientists have been looking toward space for solutions. A space habitat would not only help relieve the population pressure but would also support space exploration and in-situ resource utilization. This paper will deal with the basic requirements and determine whether the current level of technology is sufficient for setting up a space habitat.

This paper will consider a space settlement in an optimal location and will analyze the structural requirements, construction process, operational requirements, and needs of the residents. Solutions will be declared valid based on data from previous space exploration missions by NASA, ISRO, and other space agencies. This research paper's findings can be used to shift aerospace engineers' focus toward the technologies needed to make the habitat more viable.

1. INTRODUCTION

Space colonization has become a popular concept for several reasons including the survival of human civilization, space exploration, and the availability of novel resources. As we get closer to our goal of living in space, many designs for a settlement have been proposed. This paper will analyze the basic requirements such a settlement would have to fulfill and will propose one design, assuming optimal conditions.

With countries competing against each other to win the race of a successful launch, innovations are lacking. Several agencies are following in the footsteps of NASA, CNSA and ESA, rather than making their own advancements. If these agencies shift their focus to the next big mission of a space settlement, humanity could be living in space within the next few decades.

This study will provide solutions to the basic requirements for a space habitat and will suggest technologies that will make the processes within the settlement more efficient. The hypothesis is that though the structural and operational requirements can be fulfilled by the current level of technology, automated robots and systems should be the focus of engineers as these technologies will be a major help in increasing the chances for success of this habitat. Here, technologies and designs used by various space agencies have been taken into consideration to propose an optimal design, and functions of automation devices have been suggested, demonstrating the increase in efficiency. With this information, advancements in the field of aerospace engineering can be focused on automation.

2. REQUIREMENTS

Here, we will consider some of the major requirements that need to be addressed when considering a space habitat and propose a few viable solutions.

2.1 Location

Usually, when we talk about living in space, we think about settling on another celestial body, such as a planet or the moon. But an orbital habitat may have more to offer, and thus, while considering an optimal space settlement, we cannot afford to ignore that avenue. For example, an orbital habitat will be able to imitate Earth's gravity through rotation. It will also have a near-continuous supply of solar energy, thus solving any power-related issues. In addition, zero-g will ease many of the construction processes, enabling the construction of a bigger settlement. Considering the benefits of this type of habitat, for this paper, we will consider our space habitat to be in orbit.

To make the best use of the resources present in space, the location of the habitat's orbit needs to be chosen carefully. Some of the things to keep in mind are listed as follows:

1. Travel Time:

A planet near the Earth would be more economically practical and would reduce exposure to effects such as radiation and microgravity.

2. Resources:

The chosen planet should be abundant with rare or unknown resources to support space exploration.

3. Proximity to Sun:

Proximity to the Sun would provide significant amounts of solar power.

4. Atmosphere:

The atmosphere of the planet should be habitable.

Keeping the above factors in mind, Venus is one of the options to consider for the habitat to orbit around. It is closer to the Earth compared to Mars, the bizarre environment on Venus is likely to produce previously unknown ores and minerals, and it is near the Sun. As an added benefit, it has a thick atmosphere, which can help protect humans from external threats such as radiation. On the downside, the pressure and temperature on the surface of Venus are extremely high and can make life impossible. But since our habitat is in orbit, a suitable altitude will help neutralize some of the dangers, and the habitat will be built with the capability to withstand such conditions.

Therefore, the space habitat to be considered in the paper will orbit around Venus and will provide a living and working environment for permanent residents while scientists may temporarily visit the planet for space exploration.

2.2 Orbital Altitude

An orbital altitude that provides a suitable distance for researching Venus' surface, as well as its atmosphere, should be chosen. The orbital path should ensure that the settlement does not enter the planet's shadow (for example, a polar and sun-synchronous orbit would allow that). It should also provide nearly complete latitudinal coverage making a wide range of Venusian environments accessible for research. A heliosynchronous polar orbit with an altitude out of Venus' atmosphere will help protect against the harsh atmosphere (The European Space Agency, 2020, March 30). Maneuvering thrusters can be used to maintain orbit and orientation.

2.3 Artificial Gravity

To provide artificial gravity and simulate an earth-like environment, a solution could be to provide the settlement with 2 identical habitat rings that would rotate at the same rotational speed but in different directions which will provide artificial gravity and balance out the torque (International Academy of Astronautics, 2009, September). (Using equation $\alpha = - \omega^2 r$, where α = angular acceleration, ω = angular speed, r = radius of ring)

Various g-levels can be provided in the spokes, which will provide a great degree of flexibility, and allow accommodation of multiple businesses and manufacturing activities that might be seen as profitable in the future. The spokes will be attached to a hollow cylinder present around the main axle which will not be rotating. The rings will be pressurized for residents, while the spokes will remain unpressurized.

The spokes can be attached to a hollow cylinder present around the main axle., with cylindrical bearings in between the cylinder and the main axle to facilitate smooth rotation. These will be present in grooves to prevent their shifting during rotation.

Considering the above-mentioned solution, channels can be made for passenger and cargo transport in the spokes.

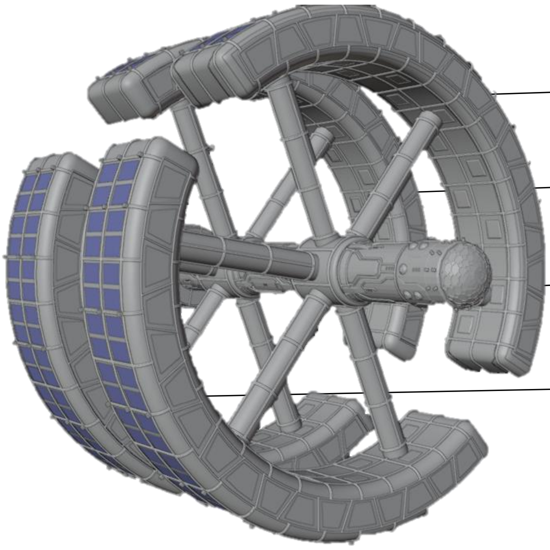

Figure 1. Basic structure depicting the two identical habitat rings and spokes.

2.4 Atmosphere

Initially, tanks will be used to store breathable air. Once operation of the air processing facilities starts, more air can be manufactured using Cryogenic Carbon Capture and fractional distillation for the separation of components of Venusian air and their subsequent purification. Electrolysis and pyrolysis facilities could be used for the production of oxygen, carbon monoxide, elemental carbon, water, and hydrogen from the components of Venusian air. Cryogenic facilities will help in keeping the gases below their boiling points. Thermally insulated high-pressure tanks will be used for the storage of the gases at cryogenic temperatures. Air will be stored as a backup for contingencies.

A centrally controlled HVAC system (installed on the ceilings) can be used for maintaining the humidity levels and temperatures throughout the settlement. The heat radiators for the HVAC will be installed on the inner curved surfaces of the habitat rings (Brennan Heating & Air Conditioning, 2019, January 7). An air filtration system will be installed to keep the air on board the settlement clean.

Gas	**Percentage**
N_2	70.115
O_2	28.000
H_2O	1.845
CO_2	0.004
Total	**100**

2.5 Food Production

High-luminous efficacy LEDs can be used as a substitute for sunlight. The CO2 concentration and humidity levels should be slightly higher in the food production areas than in the residential areas. The HVAC system can be used for maintaining the humidity levels and temperature as mentioned above.

Organic materials for food production would also be required. Initially, these materials can be imported from Earth. We could then acquire the CO2 and water through cryogenic carbon capture, fractional distillation, electrolysis, and pyrolysis as mentioned earlier. The nitrates and salts could be dissolved in water and separated into pure minerals. Other minerals containing iron, nickel, and silicon could be chemically purified. The small fraction of remaining materials could be processed into pure elements with mass spectrometry in zero-g.

2.6 Power Generation

Considering the proximity to the Sun, options for power generation include:

1. Solar Panel Satellites:

One proposed solution would be to place one satellite in the same orbit as our habitat, but slightly ahead. This would provide a direct, unobstructed line of sight between the satellite and the rectenna. If the need arises, a second satellite could be placed in the same orbit, thus, doubling its power input.

2. Solar Panel Array:

As a secondary source of electrical power, solar panels could be installed on the outer curved surface of the habitat rings.

For backup energy storage, we could use ultracapacitors.

2.7 Radiation Protection

By detecting magnetic reconnections on the Sun's surface, control rooms will predict the timings of solar flares. In such cases, residents should be moved to 'safe rooms'. The walls of the safe rooms should be composed of materials that can shield against extreme solar radiation. Examples of such compositions would be Tungsten Carbide and Ferro Boron Composite with a layer of Selenomelanin in between (it's able to shield against high amounts of X-rays, gamma rays, and neutrons) or High-Density Polyethylene with lead (it has hydrogen atoms that are good at absorbing and dispersing radiation and Lead metal is dense and provides a high level of stability) (Issard, H, 2015, *Radiation protection by shielding in packages for radioactive materials.*). Safe rooms should be located near the middle to maximize the amount of mass around residents which helps in decreasing the chances of radiation causing any damage.

2.8 Debris Protection

One solution to this problem is based on the Whipple shield. It will have an outer 'sacrificial' wall to break the projectile into pieces. This will result in a cloud of debris consisting of pieces of both the projectile as well as the wall. There should be another strong material (for example, Kevlar, which is currently used by NASA) after the outer wall to stop the debris from damaging the habitat. The disadvantage of such a shield is that it requires repairing since its strength gets reduced after getting hit. This problem can be overcome by making the shield of a self-healing material.

3. OUTSIDE THE HABITAT

Humans will have to go outside the habitat for external repairs, emergencies, and recreational purposes. To conduct these tasks, they will require spacesuits. The spacesuits will differ based on the task they have to perform:

1. Exterior repair spacesuit:

This spacesuit will be used for the inspection and repair of the exterior of the settlement. It will have a reinforced carbon-carbon fiber layer which is extremely effective in enormous temperatures and massive pressure differences. It is a flexible, light, and smooth fiber used as a primary mechanism to cope with the harsh conditions of space. It will also have a primary nano thruster. In case detached from all harnesses, one can maneuver their way with the nano thrusters. It should also have an alloyed skeletal framework powered by motors. This would enhance the performance of manual labor by providing the operator with improved precision and an increase in muscle force.

2. Civilian spacesuit:

These spacesuits will be used in emergencies such as major depressurization and should be able to withstand high amounts of force. An outer layer of Titanium infused with Nitrile will fulfill this task. The spacesuit will be solid from the outside and will be divided into plates enabling the user to put it on much faster. It will also comprise an alloyed skeletal framework and nano thrusters.

3. Recreational spacesuit:

These spacesuits will be used for spacewalks and will be equipped with a pair of tertiary thrusters to ease the process of cruising through zero gravity.

4. AUTOMATION

Robots can increase accuracy and speed up construction processes and can take part in research conducted by scientists.

4.1 Interior Construction Robot:

A robot equipped with the necessary tools, and sensors to detect gas leaks or holes, will be mounted on jigs to conduct tasks with precision. It will be able to carry out utility installation and construction of pipelines and cables.

4.2 Exterior Construction Robot:

Similar to the interior robot, the exterior robot will also be provided with radiation protection. The advantage of using robots instead of humans here is that humans will not have to be exposed to potentially harmful conditions of space.

4.3 Research Assistant:

Using a robot here will reduce chances of chemical leakage and exposure to humans. It can be tasked with transporting samples to a lab, and can handle pre-programmed tasks that might be risky for humans.

Besides these functions, robots can also be created for simple tasks such as delivery, maintenance, or household tasks to reduce manual labour.

5. CONCLUSION

Fulfilling the above basic structural and operational requirements would provide a functioning settlement for residents and scientists. As the hypothesis stated, automation would be of great help. Engineers can focus on the development of sensors that would be able to detect and malfunctions and enable the robot to work properly.

A previously unexplored planet presents many research opportunities. Some of the research avenues will be discussed here.

4.1 Research Possibilities

4.1.1 Power Generation:

Venus has powerful winds, which circulate the planet in a matter of days. But the wind speeds may vary with a change in altitude. At the top of the cloud layers on Venus, wind speeds may reach 355 km/hour. However, as the altitude goes down, the wind speeds start to increase. In the middle layer, the winds can reach speeds of more than 700 km/hour, higher than the tornado speeds recorded on Earth. Such high wind speeds could open new avenues in electricity generation.

4.1.2 Production of new ores and minerals:

The pressure and temperatures on Venus are extremely high, and its environment is vastly different from Earth. Such conditions could encourage the discovery of new minerals, ores, compounds, or isotopes. It could also enable many industrial processes that were extremely hard to conduct on Earth.

4.1.3 Manufacturing of Water:

Spectroscopic techniques can be used to identify potential Hydrogen containing compounds in the Venusian atmosphere. Identified compounds will be collected and brought to labs for testing. Various decomposition techniques to acquire hydrogen from the collected compounds can be researched (IEEE Spectrum, 2019, November 26).

4.1.4 Carbon Extraction:

Carbon will be a priority source of economic probing due to its abundance on Venus. Through elementary experiments, carbon can be used for varying purposes such as manufacturing space tethers. Various chemical and physical processes can turn carbon and its oxides into a plethora of simple and complex hydrocarbons. These hydrocarbons can either be exported for business or be turned into plastics, rubbers, resins, solvents, etc. Carbon extracted from the atmosphere will be feedstock for fuels and commercial products for local use and export.

4.2 Expansion Possibilities

In the future, new opportunities for large-scale manufacturing and processing may arise which require the expansion of facilities, or the habitat itself.

4.2.1 Demand for a Venusian Substance Increases:

It is expected that new materials with exceptional qualities will be discovered by the research labs aboard the habitat. It is natural to assume that as these new materials are discovered, new use cases shall be found for these materials, and subsequently, their demands may skyrocket. And since this habitat is the only source of these new resources, expansion of facilities must be expected. As the demand for this substance rises, the capacity for refining and production of this substance must be increased to match demand. In case the facilities remain insufficient even after expansion, new co-orbiting facilities, built specifically to refine and produce this specific substance will be required.

4.2.2 Discovery of New Material:

An extensive research and development period and facility will entail the discovery of new materials and isotopes in quick succession throughout the habitat's operational cycle. Venturing into the bizarre conditions of Venus is likely to bring a plethora of new and unique products. The discovery of new minerals, ores, and isotopes will require expansion in the production and refineries facilities. The overall industrial division will be tasked with accommodating the manufacturing and processing of these new materials, however, beyond the expansion of facilities in the habitat as the products gain market interest, co-orbiting facilities can also be delegated their manufacturing activity.

4.2.3 Co-Orbiting Facilities for Companies:

Venus is a planet with many business opportunities, waiting to be unearthed. Thus, many companies may be interested in setting up shop in orbit of it. The habitat could provide private and shared office/research spaces to such companies, but the facilities aboard it may reach their limits as the demand for access to Venus goes up. In such cases, companies may request a co-orbiting facility to be built for them. Such facilities do not have to be self-sufficient, as they can receive logistical support and assistance in sustaining them from the habitat. These facilities may belong to individual companies/organizations or may be shared among multiple such companies, depending on the number of their requirements. Having multiple interdependent settlements, in this manner, helps save costs for companies as they do not have to invest in all of the infrastructures that are required to run a fully functional settlement. By partnering up with the habitat, they can essentially outsource some of the infrastructure required to run a settlement, making smaller settlement designs economically feasible.

4.2.4 Increase in Personnel Requirement:

As extensive research continues on the habitat, an increase in the number of personnel required is anticipated. Research and production of Venusian atmosphere and substances are expected to expand, giving rise to the requirement of new types of human resources that can include research personnel with specific expertise, automation experts, and such. For this purpose, the population of the habitat may be expanded to fulfill the intellectual requirements as well as provide employment opportunities.

Once the research facilities have determined that the production of a certain material needs to be scaled up, the facility requirements (power, additional levels, raw material, transportation) are ascertained. The scaling up of utilities is done as stated:

1. The power generation system can easily be scaled up by adding another satellite. The satellite will be placed slightly behind in the same orbit as the settlement. The cargo transportation systems should be designed to have a large capacity overhead so that they can cater to the increased traffic with ease.
2. The supply of raw materials can be increased. More area can be allocated for the storage of the new material if required.
3. More levels can be added to increase the area for production and accommodate industrial operations.
4. Simultaneous research will identify substitute goods for products being produced, creating elasticity in their demand.

REFERENCES

1. The European Space Agency. (2020, March 30). *Types of Orbits.* https://www.esa.int/Enabling_Support/Space_Transportation/Types_of_orbits#SSO
2. International Academy of Astronautics. (2009, September). *ARTIFICIAL GRAVITY RESEARCH TO ENABLE HUMAN SPACE EXPLORATION*. https://web.archive.org/web/20161013004743/http://iaaweb.org/iaa/Scientific%20Activity/Study%20Groups/SG%20Commission%202/sg22/sg22finalreportr.pdf
3. Brennan Heating & Air Conditioning. (2019, January 7). *What is an HVAC System and How Does it Work?*. https://brennanheating.com/how-does-hvac-system-work/
4. Issard, H. (2015). *Radiation Shielding.* https://www.sciencedirect.com/topics/engineering/radiation-shielding
5. IEEE Spectrum. (2019, November 26). *4 Products That Make Sense to Manufacture in Orbit*. https://spectrum.ieee.org/4-products-that-make-sense-to-manufacture-in-orbit