

Mining and research hub at I5 engineering essay

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Abstract

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Dev University, Amritsar-143005, Punjab, India. In this paper the design of an

orbital space settlement named Lakshita located at L5 for 10000 residents

having area of $1 \times 10^6 \text{ m}^2$ has been proposed, with the aim of fulfilling mining

activities and space research in micro - g. All calculations are made in the

perspective of a dynamic demography which could lead to the doubling of

the population in next 25 years with initial population of 4500. The

settlement consists of one residential torus, one agricultural torus, industrial

cylinder and two docking cylinders rotating coaxially at 1rpm. 2. 3% volume

of the total is provided for two docking cylinders with 6 docking ports having

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enabled the elastic flow of space traffic providing continuous loading and unloading of cargo and passengers. Four pressurized sliding cylinders with $5.7 \times 10^5 \text{ m}^3$ volume above the down surface area moving along the spokes fulfill the need of adaptation of visitors at half the gravity level of primary settlement volumes as well provide wobble control. $1.1 \times 10^5 \text{ t}$ of pressure is provided above the down surface area of the residential torus. The power generation of 600 Mw, required for the functional need of Lakshita, will be obtained through SPS and solar panels on the central cylinder, rear end of the mirrors and two docking cylinders. The 14 hour day and 10 hour night cycle will be maintained by four mirrors attached on either side from the central cylinder. The walls of the settlement will be made up of three consecutive layers of super adobe, Nextel and Kevlar-49 respectively to provide radiation and debris protection. An assortment of various facilities like appropriate distribution and management of water through an intended network of pipelines, accurate management of waste within the settlement has been provided. Key words: Space settlement designs; selection of materials; sliding cylinders; expansion plans of settlement; atmosphere control; wobble control.

Introduction

O'Neill in 1976 with the help of NASA Ames Research Center and Stanford University established that big size spaceships (O. Neil, 1976) can be constructed to live in space. Then various other scientists proposed different designs in this field of space settlement by sketching the Bernal Sphere (Stuart M. L., 1979), Stanford Torus (Johnson, R. and Holbrow, C., 1975), and O Neill Cylinders etc. There is no other place in the Solar System which

duplicates the conditions of earth (Britt and Robert Roy , 2001). But it is mankind's endeavor to conquer the realms of outer space and beyond. In 1980, Louis J. Halle, gave his view point that space colonization (Hall, L. J., 1980) will protect human race at the time of global warfare. NASA Chief, (Griffin, 2007) has identified space colonization as the vital goal of present space flight programs. Space Colonization will lead to the solutions of many technological and sociological (Siegfried W. H, 2003) problems of our Earth. The construction of self sustained settlement would require the generation of raw materials from space itself. As taking objects in space from Earth require a large amount of energy than from various resources of space itself. Once we launch thousands of people into orbit, and build giant solar power satellites, it will be easy to lunar resources and mine asteroids (Space research associate, 1986). Lunar regolith contains Aluminum, Titanium, Iron, Lunar ice etc which can be play a major role in the construction of space settlement. The C1 and C2 types of asteroids contain high quality metal ore, and significant deposits of volatile compounds, particularly water and are suitable for our purposes and will be one of the main sources of building materials. Most of the NEAs and meteorites contain more concentration of platinum group metals as compared to earth crust which have applications in different areas like: sensors to measure oxygen and NOx levels, home safety devices to detect carbon monoxide, chemical processing sector, data storage devices, electronics applications for electrical conductivity and durability, commercial manufacture of nitric acid, a key ingredient of fertilizers, medical equipments for cancer treatment and manufacturing of pacemakers etc. Therefore these materials are high in demand on earth as well as in the space. If we consider a small nearby asteroid 3554 AMUN (Lewis J. S, 1996), <https://assignbuster.com/mining-and-research-hub-at-I5-engineering-essay/>

it has resources containing iron, nickel, cobalt and platinum group metals, amounting to about \$20 trillion; and there are numerous asteroids to be explored. The designs of space settlement considered various fundamental needs of human survival: e. g. Basic biological requirements, atmosphere, water, food, health, physiological needs, etc. with somewhat different approach. O 'Neill analyzed the location and design of the settlement as the key feature of its success. The consideration of location includes availability of solar energy, materials, transportation time, etc. For the better fulfillment of human needs the next generation hybrid designs of space settlement (i. e. composite of the basic shapes) Lewis one (Globus, Al.,. 1991) and many more came into existence. In 2006 one of the most promising hybrid designs Kalpana one (Globus, Al., Nitin Arora, Ankur Bajoria, et al., 2006) tried to amend various aspects of Lewis one. But rotational rate of this settlement is 2 rpm, which is a compromising value from the point of view of psychological factor as per O Neill's research of 1975. Structural details, Description of transportation corridors, Dimensional description, and Expansion planning are unanswered by Kalpana One. The bare minimum three criteria for deciding the location of the settlement includes propulsion cost, transportation time and station-keeping. Some balance among them is necessary as theses cannot be satisfied altogether. The proposed settlement positioned at L5 (Steg, L. and De Vries, J. P., 1965) with no station keeping (Breakwell, J. V., Kamel, A. A., and Ratner, M. J., 1974) requirement, provides an easy access to Earth, Moon and NEA's (one of the necessary requirements for the mining and construction materials). The location provides unlimited solar energy. The transportation cost of the construction materials will also be reduced as compared to other probable locations (Thomas A.

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Heppenheimer, 1986). It answers most of the above unsolved problems, with its intimate attention to detail and luxurious aspects.

Theoretical Background

On comparing the different structures, torus is best suited for mining and research hub in space; because it provides non inertial frame of reference. The cylindrical shape demands more atmospheric volume as compared to torus. The hollow space between the outer wall and the down surface will be filled with the lunar regolith (Nancy J. Lindsey, 2003), thereby shielding the living area from radiations and it further reduces the mass of the atmosphere required. The torus structure is also best suited for expansion plans. We can weave different torus above and below the existing torus for the fulfillment of the future residential requirements (approximately 25000). The final shape comes out in the form of cylinder and in this way the construction cost will reduce by avoiding the construction of fully separate settlement. Another reason for opting the torus is its structural mass. In case of cylindrical structure similar to Kalpana One the structure mass comes out to be 632 kt for 3000 persons. On the other hand our proposed design with 10000 populations has the structural mass of 550 kt ([http://settlement. arc. nasa. gov/designer/sphere. html](http://settlement.arc.nasa.gov/designer/sphere.html)). Although the sheilding mass in torus will always be high, but it can be reduced by segregating agriculture and industry as suggested by O'Neil in his NASA summer studies 1975. Different materials required to construct the settlement are given in table 1 with their description of source and uses. On placing the Industrial, research and storage zones inside the central cylinder more volume can be obtained according to requirements for these areas. Considering the area required per

person as in table 2 and total proposed population (10, 000) for whom settlement is planned, calculations have been made to find different structural dimensional parameters and tabulated in table 3. We consider the symmetrical and balanced torus structure having center of mass at center (Fig 1) with $M_1 = M_2$ (Mass of the left hand system = Mass of right hand system) and $X_1 = X_2$ (Initial position of the sliding cylinders along X axis from the center of mass). The variation in mass Δm in the settlement results sliding of cylinder from their initial position in order to balance the structure to achieve equilibrium condition $(M + \Delta m) X_1 = (M - \Delta m) X_2$ Here $X_1 \neq X_2$ Assuming small variation in mass $= (1 + 2 [\Delta m/M]) = X_2 / X_1$ Thus the relative positions of the sliding cylinders can be found to control wobbling. Similarly the positions for the sliding cylinders along Y axis can be calculated if there is any change in mass occurs along this direction. Also, if the dissymmetry of mass occurs in between the X and Y axis quarter (Fig 2), the shifting of both axial sliding cylinders can be calculated by using parallelogram law of vector addition.

Proposed design

The objective of Lakshita will be to act as an on-orbit centre for refining and zero-g manufacturing. Settlement will be immediately inhabited upon completion by an initial population of 4, 500 people, with an additional transient population of approximately 500 people (division shown in table1). Considering an annual compounded growth rate of 2. 5%, approximately the growth of a large Earth city such as New Delhi, it will be able to provide enough living area for approximately 10, 000 providing for nearly 25 years of growth. First of all we need to build a temporary base on low Earth orbit

(LEO) for processing the mined materials for space settlement construction as materials' carrying from Earth is very expensive. We will also need to carry certain material from Earth to industrial base which cannot be found on Moon, Mars or appropriate asteroids. After the programmed robots extend the base for living, the crew consisting of workers, engineers and doctors will arrive there in the artificial habitats. In this phase the required material, i. e. tons of metal and equipment is gathered before any shipment is made. The small material blocks will be constructed that just need to be assembled for settlement construction. The construction will start in lower orbit so that planes will be able to distribute the material, because they, unlike space shuttles, need less combustible and can carry more equipment and material. The overall proposed design of Lakshita will constitute outer torus for residential purpose; inner torus for agriculture purpose; central cylinder for material processing and refining; two docking cylinders at the ends of the central cylinder acting as transportation corridors; four sliding cylinders for wobble control and for providing variable g as depicted in figures 3-6. Four reflecting mirrors will manage day and night cycle. The spokes attaching the structure will act as transportation corridors, connecting the different parts of the settlement. The down surface area of the residential torus (177 m wide strip with a ceiling of 106 m) will be of $1 \times 10^6 \text{ m}^2$ (Fig 7). The agriculture torus will have down surface area of $5 \times 10^5 \text{ m}^2$ (ref. Table 4). The artificial gravity of 1g in residential down surface will be provided by the rotation of the settlement at 1rpm around the central axis to avoid the effect of coriolis forces (Theodore W. Hall, 1999, www.artificial-gravity.com/sw/SpinCalc/SpinCalc.htm; Hall, 1997).

A Gravity of 6.4 m/s^2 on the down surfaces in agricultural torus (better growth of root system of plants in <https://assignbuster.com/mining-and-research-hub-at-l5-engineering-essay/>

this gravity) and microgravity in central cylinder will be generated at same rotation rate. The best use of micro g region is obtained by developing an industrial area in the central cylinder of radius 90 m and height 360 m approximately 900 m away from residential torus. It contains material processing units like: magnetic, thermal, electrostatic and electrophoresis separator, glass fabrication, vacuum distillation etc and storage area. It also hosts different facilities like, water storage area, recreation, power production distribution unit, and control unit to keep watch on all operations of settlement. In cases of emergency like unusual powerful solar flares, water storage zone inside the central cylinder will provide shelter for a few days until the particles die down. Two docking cylinders with radius 130 m and height 60 m have three ports (one at the top and two on the periphery) each with radius 40 m are provided on opposite sides of central cylinder. Port will have a management center, which will facilitate for the receipt, inspection, assembly, checkout, and storage of all the imports and exports. Warehousing facilities have been provided in docking cylinders in order to smoothen the storage and departure. Fuel storage (3551340 m³) volume will be provided near docking port to enable all-time adequate supply of fuel. Automated transfer system will transport large amount of fuel in fuel storage containers from docking cylinders. In this Hyper-V arm will use fuel fill port device that contains an over fill and automatically flow the stored fuel into the space port. An-anti-surge valve present on the arm will prevent the fuel leakage. It also hosts asteroid mapping module, decontamination zone, and communication with the mining base. An emergency repair unit will be located at both the docking cylinders providing long term docking facilities and repairs of ship. Ports are sufficiently separated to prevent damage to

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pressurized volumes. For safety measures; industrial unit can be evacuated and sealed in case of accident. Four sliding cylinders (Fig 8) on the four respective spokes have been designed to provide wobble control. Varying value of g from 5 ms^{-2} to 1.5 ms^{-2} is usable for visitors and astronaut crew training for long term missions like Mars and asteroid belt etc. The variable gravity in the cylinders can provide new horizons for the scientists for research in the field of human behavior, nanotechnology, bio-medical research, fundamental sciences and space exploration.

Structural materials

In space there are two main threats to any structure, one is radiations and other is debris. Residential torus having curved surface area $3.2 \times 10^6 \text{ m}^2$ needs shielding mass $3.2 \times 10^{10} \text{ kg}$ to protect it from debris and radiations. Although passive shielding is very effective but it is not the best solution because of its high cost and long time needed to mine so much material from the extra terrestrial sources. We propose combination of active as well as passive shielding, which will also reduce the structure mass and further reduces the propulsion fuel cost. To obtain acceptable radiation dosage (less than 0.5 rem /year), no doubt that passive shielding is good choice because it is simple and strong. It protects the settlement from neutrons exposure and even from meteoroid's impacts but it is too massive. We suggest hybrid shielding that is active as well as passive. For passive shielding main materials used can be obtained from lunar soil (Järvstråt, N., 2002) and NEA's (Kuck D. L., 1979). We suggest four layered wall made up of Nextel (E. L. Christiansen, 2000), Kevlar (Ronald, V. Joven, 2007), Super adobe (Husain, Yasha, 2007) and Silica aero gel (Gesser, H. D. and Goswami, P. C. 1989)

consecutively. In case of windows Hydrogenous materials and light elements are expected to be more effective shields against the Galactic Cosmic Rays (GCR) than alumino silicates, which is used in current spacecraft hulls. We propose windows made up of polyethylene, (Guetersloh, S., Zeitlin, C., Heilbronn, L., et. al., 2006) electrochromic smart glass and fused silicate glass. There will be three panes of glass, 50 m wide facing towards central cylinder. RTV adhesive (Anna, E. Gunn-Golkin, 2005), an electrically neutral and chemically resistant, will be used to bind different layers. Natural views of outer space and Earth along with natural sunlight will be provided by the glass supported by a titanium support system. As windows are turned inward, a significant amount of radiation will be already deflected by the thick shielding for the ring. For active shielding we propose electromagnetic shielding which is considered to be the most convenient way to protect the settlement against ionizing radiation.(Geoffrey A. Landis, 1991). Although above proposed materials for construction will provide sufficient protection from small space debris, we propose to have settlement maneuver system similar to the one as attached in international space station to protect settlement (Bedrossian, N. Bhatt, S. Lammers, M. et. al., 2007). There will be eight maneuvers situated symmetrically four on each docking cylinder capable to orient in order to permit the movement of the settlement in different directions as per requirement. The settlement will be capable to drift by 2 - 3km distance, in the combined effect of accelerated and decelerated movement.

3.3 Design considerations

The various aspects considered while designing the settlement include atmosphere control, thermal control & humidity control, water recycling; water distribution, electricity power generation, day and night provision, rotation & wobble control, psychological aspects, transportation corridors etc. are described as follows: The atmosphere of the Lakshita will contain a partial pressure of oxygen sufficient enough to cause the movement of oxygen from atmosphere into the alveoli of the lungs ($\sim 13.4 \text{ kPa}$ or $\sim 100 \text{ mm Hg}$) for good respiration. In residential torus volume above the down surface is $8.8 \times 10^7 \text{ m}^3$, thus by considering the density (ρ) of the air 1.2 kg m^{-3} (on the Earth at sea level), the value of pressure comes out to be $1.1 \times 10^5 \text{ Torr}$. For preserve suitable living conditions we have to retain the molar fractions of the gasses constant. Earth's atmosphere consists of: 20% O_2 , 78% N_2 , and 2% other gasses (volumes). Number of moles of individual gases needed in the atmosphere of residential torus can be calculated as: $(n) = (P V) / (RT)$. Where $P =$ Atmospheric pressure (1 atm) $V =$ Volume of above the down surface in residential torus ($8.8 \times 10^7 \text{ m}^3$) $T =$ Temperature of residential torus (we consider 250°C) On calculating n comes out to be $3,601,244,066.13 \text{ k moles}$ of air. Thus number of k moles of oxygen is $n \times 0.2 = 720,248,813.22636 \text{ k moles}$, nitrogen is $n \times 0.78 = 2,808,970,371.5814 \text{ k moles}$ and of other gases $n \times 0.02 = 72,024,881.3226 \text{ k moles}$. In order to maintain the correct composition, a system of photo acoustic laser/ lamp sensors spaced throughout the station will detect trace gases through spectroscopy. Acidic gases and CO_2 will be removed through lithium hydroxide filters, while odors and off gassing products will be eliminated with activated charcoal, through catalytic oxidation or advanced filtrations. While <https://assignbuster.com/mining-and-research-hub-at-I5-engineering-essay/>

particles present in the atmosphere will be filtered through ionic grids. Regeneration of gases from waste collected from different processes will take place simultaneously in the plants positioned under the down surface. Temperature and Humidity Control System [THC] includes control of airborne particulates and airborne microorganism (Scull, T., Devin, M., and Bedard, T., 1998). These systems, are provided in the residential area, utilize Condensing Heat Exchangers [CHX] to remove water obtained through evaporation, breathing and heat from the residential atmosphere. Initially, water could be obtained by melting ice extracted from the surface of moon using solar energy and then purified. Also, the first cargo ships arriving at the location will need to carry water supplies. By considering the costs of transportation of water from Moon and/or from Earth, water will be constantly recycled inside the settlement. According to the NASA's summer study per person per day requirement of water is 31 kg. We assume higher end of water requirement as 40kg and hence 73000 m³ volume of water will be stored in order to fulfill six months requirement of habitats in a cluster of interconnected tanks located at the center of the space settlement. The residential and agricultural areas are provided with two water pumping centers from where supply of water can be supplied. For the distribution of purified water through pipeline network (fig 9) two underground purification plants are provided. Pipes will be connected to each house at one end and to water distribution plant at another end. Disinfectants will be added to the reclaimed water to prevent the growth of pathogenic organisms. The Biological Water Processing (BWP) (David, Kortenkamp and Scott, Bell., 2003) sub-system will remove organic compounds. Then the water will be passed to a Reverse Osmosis (RO) subsystem, which will recover 85% of the

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water and rest of the 15% will be recovered from Air Evaporation Subsystem (AES). These two streams of grey water from the RO and the AES will be passed through a Post- Processing Subsystem (PPS) (Pete Bonasso, 2001) to be purified and make potable water. As the system is closed like a loop, it also needs to be governed by recycling of waste. Different system technologies can be used to deal with wastes like electronic components, including steel, copper, aluminum and plastics. For organic wastes, we suggest an anaerobic digester (http://www.foe.co.uk/resource/briefings/anaerobic_digestion.pdf) which can be deployed in the agricultural torus. Methane formed as a side product in this digester will be used for household purposes. To manage the inorganic wastes including industrial wastes, we suggest a microwave incinerator or any such system can be used. Under the roads pipelines will be provided for the flow of waste and its byproducts to their respective sites. While deciding for the power source we considered the use of nuclear as well as solar options but given the fact that square meter of space receives almost 7.5 times more sunlight in comparison of Earth and potential risk associated with nuclear energy, makes solar energy (John, K. Strickland, Jr, 2010) the first choice for power production. Moreover solar energy has been chosen over nuclear power due to the radiation hazards and disposal issues related with nuclear power. Solar power station (SPS) will be used to meet the power requirements of settlement. The current requirement of energy in U. S. A. (http://en.wikipedia.org/wiki/List_of_countries_by_electricity_consumption) is 33KWH per person. Because of the high degree of automation we assumed the requirement to be 40KWH per person, which includes all the residential, agricultural and industrial needs. Total power requirements of the settlement <https://assignbuster.com/mining-and-research-hub-at-I5-engineering-essay/>

will be 400MWH. This requirement can be fulfilled by having total solar panel area (<http://settlement.arc.nasa.gov/designer/sphere.html>) of 3.6×10^6 m² on SPS placed at L4. The power produced can be transferred to the settlement using microwaves. The space ships with raw and processed material will arrive and depart from the docking ports. Each docking port have storage areas, two elevators which further connects to the elevators of the central cylinders. In order to have access to different operational units of settlement, central cylinder is connected with the four spokes of 50 m each. A circular passage of diameter 30 m containing four elevators is provided in each spoke. Fig 10 shows transportation corridors in settlement describing the road map for export facilities. The proposed design considers all psychological requirements of the residents, like line of sight which is more than required 64 m, large overhead clearance, external views, day and night cycle, contact with external environment at ports etc. Silica Aero Gel is used for sky like padded surface inside the settlement. We plan to give a 14 hour day and 10 hour night to residents of settlement by introducing two circular reflecting mirrors at 45° and two frustum shaped mirrors made up of Biaxial Oriented Polyethylene Terephthalate polyester (BOPT) (W. Goetz, 2005). It has the potential to reflect up to 97 % of sunlight. To ensure day, two circular mirrors are attached on either side of the cylinder which will reflect the sunlight onto the frustum shaped mirrors attached at the center of the central cylinder and further redirects the sunlight into the residential & agricultural torus through specially designed windows made up of electro chromic smart glass (Deb k. Satyen, 2000) which will control the intensity of light. The two Helio sensors containing photoreceptor cells will permanently determine the position of the Sun towards the mirrors. By connecting them

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to the rotating system of the mirrors, they will always keep them face to the Sun, so that the amount of light reflected onto the surface of the torus will be maximum. In order to ensure constant rotation, Pulsed Inductive Thrusters [PIT] (Lee, dailey, C., Ralph, H. Lovberg., 1993) will be attached in balanced pairs around the structure. The PIT will provide an impulse of 200 times per second & thrust at the rate of 2. 79 N/3350 sec by the input of 1 MW of power. The wobble control will be required as the mass distribution changes over time as people and materials move about. Its remedy achieved by using the movement of sliding cylinders as shown in the fig. 5 based on the principle of the moments. At the time of wobbling these sliding cylinders will slide in the opposite direction to balance the structure. The slide distance of these cylinders will be very less (even less than a meter). Their motion is controlled by central control unit in the central cylinder.

4. 1 Conclusions

The design ensures the stable and comfortable settlement from the structure point of view, operations and human factors (area allotted 180 m² per person and 180 m line of sight). Transportation corridors, storage area, water distribution, water recycle, waste disposal are considered while designing the settlement. Two Docking cylinders enable simultaneous docking & loading/unloading of cargo & passenger ships. Two mirrors are placed on either sides of the central cylinder to provide Day & Night cycle. Selection of materials is done according to the available materials on lunar surface and NEAs. The residential torus and the industrial area are separated from each other on account of safety. The agricultural torus between the central cylinder & residential torus tend to ease the supply of food & movement of

residents to agricultural torus in case of any emergency. Future expansion of the settlement can be done according to the need by constructing another torus on the previous torus which will save energy and economy instead of designing another separate settlement. Four sliding cylinders move along the spokes to provide wobble control as well as to enable the visitors to adapt. Therefore, we can conclude that the proposed design of space settlement showed us the path of future into reality.