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ANALYSIS OF SPACE HOTEL AND ITS CONSTRUCTION CHALLENGES

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ABSTRACT

First, a conceptual design is created of the Space Hotel. A CAD model of the hotel is created with enough detail to present the rough conceptual design of the Space Hotel. The spin rate of the hotel in order to produce artificial gravity is determined. Also, determined the other needs of the human guests of the hotel are determined. These needs will include electricity, food, water, waste removal, and crew. Cost models are developed to estimate the cost for launch, assembly, and operation of the hotel. Using these cost models, the cost with respect to the number of guests and the duration of the stay of each guest is determined. In addition, trends are shown which illustrate how a Space Hotel can be operated in a cost-efficient manner. The prospects for the development of commercial hotels in space, and shows that - having already begun with the recent commercialisation of the space station it is increasingly accepted that this is likely to become a lively new field of business within little more than a decade. The key enabler is the availability of low-cost access to space through the operation of reusable passenger-carrying launch vehicles, the development of which requires investment equal to just a few months of existing space budgets. When this happens, competition will lead to rapid development of progressively more exotic facilities as companies exploit the unique environment of space to provide guests with ever more entertaining services. some of the civil engineering topics that will arise as orbital accommodation grows from assemblies of prefabricated modules, to large structures assembled in orbit, to rotating structures offering 'artificial gravity', and eventually to buildings on the lunar surface. the prospects for the development of commercial hotels in space; it shows that it is increasingly accepted that this could become a lively new field of business within little more than a decade. The key enabler is the availability of low-cost access to space through the operation of reusable passengers-carrying launch vehicles, the development of which requires investment equal to no more than a few months' worth of existing space budgets. When this becomes available, competition will lead to rapid development of progressively more exotic facilities in orbit as companies exploit the unique environment of space to provide guests with ever more popular services. Discussed are some of the Civil Engineering topics that will arise as orbital accommodation grows from assemblies of prefabricated modules to large structures assembled in orbit, including rotating structures offering "artificial gravity ", and eventually to building on the lunar surface.

I.INTRODUCTION

Since the ancient times, people have always dreamed of going to the space. Only astronauts have been able to go until now, but progress has been made on efforts to enable even private citizens to experience space, and space travel is finally about to become an industry. The era of space travel early on, and has proposed a space hotel concept Shimizu foresaw. The space hotel is a large space structure that is 240 meters long. It consists of four sections: the energy supply, a guest room module, a public area, and a platform. The space hotel would float in a low earth orbit and would allow people who have not received any training to enjoy space travel. The greatest objective of space travel is to see the earth. Travelers would be able to view the glowing globe of earth in the clear blue, the thin veil of the atmosphere, the beautiful clouds, and the dawn of sunrise on earth. They would also spend their time stargazing, playing sports and eating in zero-gravity space, and communicating with the earth. In order to understand the potential role for civil engineers, a most important fact is that in all the market research to date the majority of people say they would like to spend several days in orbit, rather than only a few hours Consequently, in order for space tourism to reach its full potential, it will be essential to provide accommodation in orbit - that is, space hotels. The numbers show impressive potential. It is easy to calculate that when the number of people staying in orbit for a few days reaches 100,000/year. When the number of passengers reaches 1 million/year, some 20 years from now if serious efforts start soon, there will need to be accommodation for more than 10,000 people in orbit! Since no-one has identified any other space activity that offers anything approaching this level of demand. A booming space hotel industry will generate business for all the different activities involved in the hospitality industry as it becomes the 'front line' of humans' expansion into space. Similar to hotels on Earth - or cruise ships.

Today's technical progress allows it to develop, design and build more and more reliable possibilities to get into space without penalties in safety. New technologies like re-usable rockets, alternatives to reach the orbit and better understanding of the behaviour of human bodies in space make it cheaper to live and experience the borders of our world. These leads to an increase of space tourism which becomes more and more interesting after people has already been sent up to the International Space Station. The price for such a trip is still high. To allow more people with curiosity and passion for space to experience this foreign environment it is necessary to reduce the costs and grow the market for space tourism. The commercial usage of already developed space product’s makes this possible. The vision of a space hotel is only one of several ideas to over more and more people what our ancestors only dreamt about. But these undertakings do not only provide port; it also helps to accelerate the development of space technology and to achieve more knowledge about psychology and physiology. This report shall give an idea how a project on the basis of a space hotel could be realized. It includes _nancial aspects as well as timelines and investigations of available technology. More detailed reports for technical details have been made by Vehicle Concept and Layout, Human Aspects including Life Support and Mission Teams, Logistics and Operation. These can be found in separate reports.

There is a mention made of the space hotel itself like size, basic concepts, power and thermal facts, the life support system and communication as well as its orbit in space. It also includes operational information like preparation of tourists, number of crew, stand guests, safety and medical aspects, the mass budget and logistics. The content of this Overall Coordination report is divided in six chapters. The _rest one is about the requirements and constraints which are set. This includes also a part about the communication and project time schedule. The second one explains the space hotel concept. The physical layout, mass budget, cost budget, assembling of the space hotel, guest and crew schedule are integrated in this chapter. The following is about logistics of the space hotel which involves launch site, launchers, capsule, orbit, launches per year and the resupply missions. The human aspects are reported in the next part and includes the training and treatment of the tourists before and after the light. The last two chapters are about the _nancies and risk management which involves an o_-nominal case.

FIG.1: VOYAGER STATION.

Orbital Assembly Corporation (OAC) has unveiled plans to construct the world's first space hotel, called the Voyager Station, in low Earth orbit in 2025. The space station is expected to operate with artificial gravity and feature restaurants, cinemas, a spa, concert venues, viewing lounges, bars, libraries, gyms, and rooms for 400 people. A fleet of patented in-space assembly robots is expected to build the VSS, which could be fully operational by 2027. Although there are many economic difficulties facing the world today, there is also a prospect of a new 'Golden Age' of world-wide economic growth based on humans' ever-growing accumulated knowledge. However, in order to achieve this, it is necessary to build on sustainable foundations, which requires economic policy- makers to aim in the right direction. One most important requirement is for economic policy-makers in richer countries to facilitate the growth of the new industries that are continually needed to re-employ those leaving older industries as they automate progressively and migrate to lower-cost countries. An important direction which has recently begun to receive recognition as a potentially major new field for commercial activity is passenger space travel. The two following predictions show the scale of the potential importance of this new field in the coming years.

Prediction 1: "Popular space travel will do for the 21st century what aviation did for the 20th century". Passenger space travel will grow from zero to more than $1 trillion/year, creating new employment for tens of millions of people, and profoundly changing our daily life on Earth.

Prediction 2: "Within little more than 10 years, space will be the front line of the hotel industry". Space hotels will be a focus of media interest, and they will show rapid development as they compete to attract guests with more and more advanced facilities exploiting the unique environment of space.

Many people are skeptical about these possibilities, since they think that tourism in space must be impossible "...because if it was possible, NASA would be doing it". However, this logic is based on an unfortunate misunderstanding about the behaviour of government space agencies.

: THE CENTRE OF RESISTANCE; GOVERNMENT SPACE AGENCIES:

Sadly, government space agencies have no interest in helping taxpayers travel to and from space. They currently receive budgets of $25 billion every year from taxpayers (Nasa $14 bn, Europe $6 bn, Japan $3 bn, plus a few billion in Russia and other countries)- but they use less than 1% of this for work that is relevant to making passenger space travel available. They are not trying. However, this is not because passenger space travel is not feasible. Because Nasa's leaders have decided not to make it accessible via the Nasa web-site, it is not widely known that Nasa published a report 'General Public Space Travel & Tourism' [O'Neil et al, 1998] which confirms that space tourism is feasible and realistic. The report's major conclusions were:

1. almost anyone will be able to travel to and from space without difficulty;
2. sub-orbital space flights can start with today's technology; and
3. tourism will become the largest business activity in space. The report also recommended actions by Nasa and other US government offices to help this development which will bring major economic benefits [O'Neil et al, 1998].

However, the present administrator of Nasa is not implementing the report's recommendations - and other countries' government space agency leaders take the same view: that they need not use any of their funding to help make space accessible to taxpayers! This policy is completely different from governments' role in aviation, which has for many decades been to aid the growth of commercial passenger air travel - which has grown into a global industry with revenues of nearly $1 trillion/year, creating employment for tens of millions of people. By contrast, although commercial passenger space travel is known to be feasible, space activities are still mainly government activities funded by taxpayers at $25 billion/year, and they employ far fewer people. This economically disastrous situation is a left-over of the cold war, during which Nasa was established to compete with the Soviet Union in publicly visible 'space missions'. For decades during the cold war space agencies grew used to receiving enormous government budgets with which they did not have to earn a profit - and they are very reluctant to change. This problem has now reached such a critical level that proposals are being made to take funding away from space agencies and give it to organisations that will develop passenger-carrying vehicles [Rogers, 2000]. It is increasingly recognised that the aviation industry has the experience and capabilities to do this successfully, and collaboration between space and aviation interests is consequently also specifically being advocated [Collins et al, 1999].The traditional viewpoint of government space agencies is now due for revision as governments progressively cut back economically unproductive expenditures, and the public increasingly expresses its desire for space travel services. However, at least until government space agencies are radically reformed, it is a major mistake for the general public to rely on them to make space travel services available like air travel - since they are extremely reluctant to give up their comfortable and privileged position of receiving $25 billion every year from taxpayers, none of which they even have to pay back - let alone earn a commercial rate of profit.

:AN INTRODUCTION TO SPACE TOURISM:

Man is curious by his nature and space travel is utter most curiosity for mankind. Few in million people got chance to sort their curiosity but what about rest millions?? When a common man would be able to fulfil his dream destination?? Millions of questions pertain in mind but there was no answer for this couple of years ago. However, the distant dream of exploring space by common man turned into reality by the introduction of space industry. People would like to experience space travel for various reasons. And the aim to give brief idea about space tourism industry, its emerging trends and how much it is commercial viable and what are the risk factors involved in it followed by the conclusion. Further the aim to discuss potential of space tourism and forecasting the expected revenue and estimating the investment costs for developing space tourism. Introduction Space tourism encapsulates the notion that paying passengers will have the opportunity to travel beyond Earth's atmosphere and experience orbital flights, prolonged stays in rotating space hotels and participate in research, entertainment and even sport. However, it is important to emphasize that this concept will necessitate a paradigm shift in how space is perceived, constituting not only the journey but also forming the destination. Space tourism for a literal understanding of the term may be split into two words, space and tourism. Space has been defined by many dictionaries as: A boundless three-dimensional extent in which objects and events occur and has relative position and direction. The empty area outside the earth's atmosphere, where the planets and the stars are." (Cambridge Dictionaries, 2000).

The word space invigorates the enthusiasm in any curious individual towards the darkness of the universe, not literally but, one tries to see the light beyond this darkness. Curiosity gets the better of us. With all due respect to the people who believe in the saying curiosity kills, it's after all curiosity that got mankind reach the heights it has. Space exploration, aerodynamics, technology, communication, satellites, orbits and the list goes on-and-on are all attributed to curiosity and enthusiasm for aviation and space exploration. Space is a term that can refer to various phenomena in science, mathematics, and communications. In astronomy and cosmology, space is the vast 3-dimensional region that begins where the earth's atmosphere ends. Space is usually thought to begin at the lowest altitude at which satellites can maintain orbits for a reasonable time without falling into the atmosphere. This is approximately 160 kilometres (100 miles) above the surface. Although the frontier between the atmosphere and space is not officially defined, it is generally accepted that space begins 100 km from the surface of the earth. Tourism derivates from the word "tour" which means a journey in a circuit. where the most essential word is circuit which signifies a return journey to the origin point. Tourism is travel for recreational, leisure or business purposes.

The World Tourism Organization defines tourists as people who "travel to and stay in places outside their usual environment for more than twenty-four (24) hours and not more than one consecutive year for leisure, business and other purposes not related to the exercise of an activity remunerated from within the place visited". Tourism has become a popular global leisure activity. In 2007, there were over 903 million international tourist arrivals, with a growth of 6. 6% as compared to 2006.International tourist receipts were USD 856 billion in 2007 in India. The first terrestrial vehicle penetrated the orbit surrounding Earth over three decades ago, yet since this time space has remained strictly within the domain of national governments and professional Astronauts. Over the course of human history there has always been a strong drive to explore and travel to new and exciting places. Space exploration has captured the imagination of the general public for the last 30 years; it is only natural that people are now beginning to ask if and when they too might venture into space. Space and tourism have both developed at an equally rapid pace, and the potential of both together is definitely going to grow further. Although human spaceflight is currently the privilege of a few space-exploring nations, recent advances in space technology and entrepreneurship are about to change the status quo. China, with the assistance of Russian technology, was able to place an astronaut in space in 2003 in a fraction of the time that it took other space powers, such as the USA and USSR, to do this. The first credible private space-tourist venture is already a reality. The first space tourist, Denis Tito, flew in 2001 in a government vehicle, although his flight was privately funded, whilst in 2004 the first spaceship became a reality. Thus,

• Space tourism: providing services for humans to access and experience space for adventure and recreation

• Space tourist: a person who travels to and experiences space for adventure and recreation (also space traveller, space client, space passenger).

Essentially space tourism is of 2 types 1. Sub orbital 2. Orbital Sub orbital as the word suggests, Sub orbital flight, is a flight short of orbit altitude. Currently priced at around US $1,00,000, a sub orbital flight would take a tourist to an altitude of about 100 Km above the earth on a trajectorial path, at the peak of which one would experience zero gravity and can see the earth's curvature and the hollow black space around. The space hotel will probably shut off its engines well before reaching maximum altitude, and then coast up to its highest point. During a few minutes, from the point when the engines are shut off to the point where the atmosphere begins to slow down the downward acceleration. This flight now requires a training of about a week.

FIG.2: SPACE TOURISM.

: THE UPCOMING SPACE HOTEL INDUSTRY:

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In order to understand the potential role for civil engineers, a most important fact is that in all the market research to date the majority of people say they would like to spend several days in orbit, rather than only a few hours [Collins et al, 1995]. Consequently, in order for space tourism to reach its full potential, it will be essential to provide accommodation in orbit - that is, space hotels. The numbers show impressive potential. It is easy to calculate that when the number of people staying in orbit for a few days reaches 100,000/year (which the estimates could happen within 11 years if development of Kankoh-maru started soon), the number in orbit simultaneously will be about 1,000 people. This will require several hotels accommodating well over 1,000 people. When the number of passengers reaches 1 million/year, some 20 years from now if serious efforts start soon, there will need to be accommodation for more than 10,000 people in orbit! Since no-one has identified any other space activity that offers anything approaching this level of demand, we reach a conclusion that is still not widely appreciated - that the hotel industry is going to become the largest employer in space. In 1998 the head of Nasa stated that "...within 50 years a space hotel is not inconceivable." However, already in the year 2000 the company is marketing the Russian space station as a hotel. In doing so, is pioneering the new world order for the space industry, and has demonstrated that asking the head of Nasa about space hotels is like asking the head of the Air Force about package-tours: he has no useful knowledge of the hotel industry - which is a commercial activity ten of times larger than the space industry. Of course, until reusable passenger launch vehicles become available, the cost of travel to Mir will remain very expensive, some $20 million per passenger, preventing the market growing much. But MirCorp already have their first customer.

FIG. 3: SPACE INDUSTRY

II.LITERATURE REVIEW

CAROL PINCHEFSKY (25 JULY 2012): Space has been much in the news lately, particularly with the death of astronaut Sally Ride. But how much do you really know about the “final (some would say “next) frontier?” Take this quiz and find out.

G B LEATHWERWOOD (22 MAY 2011): In 2009, Manhattan Beach, CA-based company Solaren, Inc. signed a contract with Pacific Gas & Electric (PG&E) to provide 200 megawatts (MW) of clean, reliable electrical power to customers at a rate comparable with existing power generation facilities.

ALAN BREAKSTONE (11 APRIL 2011): A thoughtful look at the last 50 years of human spaceflight On April 12, 1961, a young man from a small Russian village experienced something no one had ever experienced before: the thunder and shake of over 800,000 pounds of rocket thrust erupting beneath him. As Vostok 1 broke free of its launch restraints, Yuri Gagarin triumphantly yelled, “Let’s go!”

ALAN BREAKSTONE (08 DECEMBER 2010): Dragon goes to space and back Space Exploration Technologies (SpaceX) successfully orbited and recovered its first

Dragon space capsule today. This marks the first time a private company has successfully returned an orbiting spacecraft to earth.

CAROL PINCHEFSKY (19 JANUARY 2012): May see the light of day When Richard Garriott de Cayeux, the founder of the Ultima series of computer games and the world's sixth space tourist, went to the International Space Station (ISS) in 2008, he didn't just kick back and bask in zero gravity. No, during his twelve-day journey he conducted experiments on the crystallization of protein molecules, took photographs, conducted an art show (really) and…made a horror movie.

PATRICK COLLINS (25 MAY 2009): Come on, Norm - we know you know! A "Review of United States Human Space Flight Plans" chaired by Norman Augustine has recently been announced, to report at the end of August or later. A potentially important piece of good news is that "stimulating commercial space flight capability" is one of the subjects to be addressed by the review.

G B LEATHWERWOOD (27 MARCH 2009): Or just the beginning? Dr. Simonyi is currently on his second trip to space, which is the seventh civilian trip brokered by US company Space Adventures . However, it will be the last for civilian space explorers for the foreseeable future. Due to expansion of the International Space Station (ISS) crew from three to six starting in April, there will be no extra seats aboard the Soyuz capsules for non-professional space travellers.

EVOLUTION OF SPACE HOTEL

The technology required to design an orbital hotel is much simpler than that in a passenger launch vehicle, or even a space laboratory like the International Space Station since there is no need for high-speed computers and data-communication systems, advanced research equipment, accurate attitude-control and so on. Early living quarters require no more than what has already existed for decades; later on, 2nd and 3rd generation hotels will be much larger and will include resort hotels, entertainment complexes and sports centres. The following lists the major steps in this evolution.

- Prefabricated modules: The first phase will comprise prefabricated modules which can be launched as units and connected in orbit, operating in 'zero G' like Skylab in 1973 or today. Some designs may include inflatable sections, which can be an economical structural method.
- Module clusters: In order to accommodate more guests, clusters of modules will grow ever larger. An interesting feature of orbital hotels is that it will be possible to add new rooms progressively as required, which is not practical for hotels on Earth, which usually remain as they were constructed.
- Large chambers fabricated in orbit: In order to be able to offer new services, larger chambers will be fabricated in orbit. For economy, prefabricated modules will have standard diameters, constraining the range of interior design possible; once the step is made to fabricate larger chambers in orbit there are few constraints on their shape, and no clear limit to their size. Buildings in micro-gravity can be very light: the only significant structural stress is that of internal air pressure of a maximum of one atmosphere. One attractive approach will be to fabricate large structures from large numbers of identical structural units. One use of large orbital structures that seems like to become popular will be sports, which will be

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fascinatingly different in 'zero G'. The large economic impact and the huge global popularity of major sports events such as the soccer 'World Cup' is an indication of the potential revenues that could be earned from novel sports events in an orbiting stadium. For this reason, preliminary conceptual work has been done on the design of orbiting 'sports centres' [Collins et al, 1994], including three different facilities, a gymnasium [Collins et al, 1996], a rotating swimming pool [Collins et al, 1998] and a sports stadium 100m long [Collins et al, 2000], as discussed further below.

- Rotating structures: In surveys, many people express a preference to stay in orbiting facilities that offer 'partial gravity' as well as zero-gravity. In order to enable guests to experience partial gravity, space hotels can be set rotating. In principle this is a simple idea, which has been under consideration within the space industry for decades. However, it adds complexity and constraints to the design and construction of a space hotel. The rate of angular rotation must be limited in order to minimise Coriolis forces acting on guests moving radially, which could feel unpleasant, as discussed in [Matsumoto et al, 1989]. Interior design principals for rotating accommodation facilities are discussed more broadly in [Hall,1999].
- Co-orbiting facilities: As the number of different LEO facilities grow, there are good reasons for siting them in a small number of common orbits [Collins et al, 1986]. In addition to improving their overall safety, this will open up possibilities for local travel between co-orbiting facilities, using 'orbital taxis' and even 'orbital scooters'.

FIG. 4: SPACE HOTEL

: SERVICES OFFERED:

From market research, most people wish to look at the Earth from space - and everyone who has done so has said that it is extremely impressive to see our home planet Earth against the blackness of limitless space. For some guests the philosophical or spiritual experience of meditating on humans' apparently unique situation in nature - as intelligent beings who have evolved to consciousness and are now on the verge of moving out towards an apparently limitless future in space - will be extremely rewarding. Learning from one's own physical experience about humans' situation in the universe will surely be educational in the most profound sense - and is entirely appropriate for the start of a new century and millennium in which humans are going to spread out from our cradle, Earth. On quite a different level, living in weightlessness or 'zero-G' is said to be hilarious. All activities are transformed, even the most ordinary ones such as undressing or brushing one's teeth - when things don't drop but float when you let go of them. In addition to daily living, there is a limitless range of possible entertainments to take advantage of this. For example, by playing with water in a dedicated room small groups of guests can witness the true fascination of 'zero G' - and children can try unlimited tricks on each other! For more

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energetic guests, all sports will be fascinatingly transformed in weightlessness. Perhaps the ultimate will be the possibility of actually flying like birds by using fabric wings, once there are sports facilities 50 metres across. The amount of lodging options available to travellers is higher than ever before. In order for a hotel to stand out, it not only has to have the basic rooms and amenities but also luxurious services.

FIG.5: SERVICES OFFERED.

ORBITAL HOTAL ENGINEERING TOPICS

Once launch costs have been reduced sufficiently for orbital tourism to become a substantial business, the cost of all activities in space will fall proportionately, and the cost of employing staff in orbit will fall to a level comparable to employing construction staff in the North Sea or Alaska. Preliminary consideration has been given to construction projects that go beyond the simple docking together of pre-fabricated modules, as is involved in the ' International Space Station'. Study of these projects raises issues in several new areas that are ripe for innovative work - and which will both draw on and in turn contribute to civil engineering on Earth. The following is a partial list of such topics.

: STRUCTURAL DESIGN:

A central issue is the overall design of large structures to remain air-tight over long lifetimes in the vacuum and 90-minute thermal-cycling environment in LEO. Drawing on design approaches for aircraft, ships and pressure-vessels, they will be designed for ease of monitoring and maintenance, and the design methodology will evolve as progressively larger structures are built, as also occurs in terrestrial engineering practice.

: OPTIMAL COMBINATION OF ROBOTIC AND CREWED ACTIVITIES:

The construction industry on Earth already employs robots for a number of tasks, which is growing steadily as robots become more sophisticated. Use of human-tended robots derived from these will be cost-effective for a range of assembly-related activities in orbit, particularly such repetitive tasks as connecting standard structural components together, and checking features on the external surfaces of structures.

: 'GROWTH' OF ORBITING STRUCTURES:

The possibility of progressively adding sections to orbiting structures is a major difference from terrestrial buildings. It will add a new dimension both to the business side of design and management of orbital hotels, and to the engineering side, since it will be necessary to monitor and control hotels' centre of mass (CM) continuously for such basic tasks as attitude-control and station-keeping.

: ROTATING JOINTS:

In hotels containing a rotating zone, there will be at least one rotating joint between the rotating and non-rotating zones, which will probably be several metres in diameter in order to allow movement of large numbers of guests.

Such a joint will also need to provide considerable structural strength and vibration-damping, depending on the overall hotel design, and carry a number of utilities, including electric power, air-conditioning and plumbing. These requirements seem likely to be sufficient to create a substantial niche for the engineering firm that gains a lead in this area.

: PEOPLE MOVERS:

Where large numbers of guests use a facility like a stadium, there will be a need to be able to move them safely. Various different techniques have been proposed to date, including handles moving along guide-rails, moving cables, air-tubes and others, but until more research is done, it is difficult to judge which means will be preferable.

: LARGE AIR MASSES:

Preliminary study of a 100m-long sports stadium led to the conclusion that the very large single air mass some 300 tons - that it will contain will require the development of a new design philosophy different from that used in civil engineering on Earth, due to differences between weightlessness and the terrestrial environment

: UTILITES AND REQUIREMENTS OF SPACE HOTEL

: PLUMBING:

An interesting challenge will be designing the plumbing systems for hotels with hundreds of guests and staff. For example, what kind of pumps will be best for the novel task of moving sewage along pipes in micro-gravity while preventing the possibility of any reverse flow? The design of both fresh-water and waste-water systems will need to be integrated with systems for recycling water to different standards for various purposes, and with the compacting of residual waste for return to Earth, or for use in recycling plants separate from the hotel.

: WATER, HYDROGEN &OXYGEN SUPPLY:

Due to the relatively high cost of carrying resources such as water to orbit, hotels will use at least partial water-recycling systems, perhaps 80%, even in the early stages, since the technology is already well developed on Earth. In addition, water can be split using solar electricity into hydrogen and oxygen, which are key rocket propellants, and this is likely to become a significant business activity. While a pool is likely to be a popular guest facility the water it contains has a large mass - of the order of 1000 tons, making its launch cost a major investment. The possibility of using the water in a pool for multiple uses, including as shelter from radiation, and reserve for propellant manufacture, could help to amortise the cost, making such multi-functional design important. The demand for water and propellants at orbital hotels could be a key step in developing the lunar economy by creating demand for exports of lunar ice, if it exists in a readily usable form, or oxygen extracted from lunar rock - though water delivered from comet remnants is expected to be very price-competitive.

: ENERGY SUPPLY:

The electrical system of the International Space Station is a critical resource for the International Space Station (ISS) / Space Hotels because it allows the crew to live comfortably, to safely operate the station, and to perform scientific experiments and activities. The ISS electrical system uses solar cells to directly convert sunlight to electricity. Large numbers of cells are assembled in arrays to produce high power levels. This method of harnessing solar power is called photovoltaics. The process of collecting sunlight, converting it to electricity, and managing and distributing this electricity builds up excess heat that can damage space hotel equipment. The process of collecting sunlight, converting it to electricity, and managing and distributing this electricity builds up excess heat that can damage space hotel equipment. The ISS electrical system uses solar cells to directly convert sunlight to electricity. Large numbers of cells are assembled in arrays to produce high power levels.

: AIRLOCKS:

In contrast to the narrow airlocks used on the space station today, there will be a need for wide airlocks - of some 2m by 1m or more - in hotels and passenger vehicles. This is an obvious case for the development of a world standard, in order that all vehicles should be able to dock together - although such a standard is likely to be 'multi-part' in order to enable a range of utilities to also be transferred through airlocks.

WHAT TYPE OF OBJECTS NEED TO SURVIVE IN SPACE

Various craft must be built to stand up to the extremes of space. Satellites, shuttles and even extravehicular mobility units (EMU) all need to have components that protect from impacts, pressure, radiation and temperature swings. Since these all need to withstand similar conditions with only the levels varying, testing for survivability overlaps for many types of space hotels. Satellites are the most common space hotel. Earth has 1,500 active satellites in orbit, both commercial and government-owned. Today, everything from GPS to communications come from satellites. If one of these orbiters fails, millions of users could find themselves at a loss. Additionally, the company operating the orbiter would need to pay for another launch. Testing satellites for space ensures that companies' investments in their space hotel are well-placed. Individual materials need testing on the craft, and the systems require examination, too. For satellites, the batteries, fuel cells, solar panels, communication system, electrical components and antennas are only a few of the elements we test to ensure they will operate in concert correctly once the device reaches orbit. Satellites destined for geostationary orbit require tests to verify the operation of their propulsion and the longevity of onboard systems to allow the craft to last for ten years or more. These larger satellites have more complex systems, more parts and consequently, require more testing. Even smaller craft in lower orbits still need testing to ensure they can make it to orbiting altitude safely and do their jobs correctly. By putting small satellites through space simulation testing, we can see how the device will survive in the temperatures, humidity and pressure of space. In addition to the satellites, the equipment aboard them, including communications devices and cameras, need to have the durability to hold up to the same conditions. Space simulations can help confirm that these devices have adequate protection from the harsh conditions they will experience during use. While ensuring the overall space hotel and its equipment will hold up during use, before building the craft, engineers need to know the materials used will not fail when subjected to the extremes of space.

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HOW MATERIALS TESTING ENSURES SURVIVABILITY IN SPACE

FIG. 10: MATERIALS TESTING.

: IMPACTS:

Man-made and natural objects bombard orbiting satellites daily. Impact testing ensures materials can stand up to intense hits. Over time, the number of defunct satellites still in orbit has increased. These shells create large amounts of space junk around the Earth, and any craft in orbit will experience several impacts from this refuse. Like the current satellites, older models had similarly durable constructions. So, their materials are robust and can create significant damage to new satellites that can't withstand the impacts. n orbit, space junk is not the only problem for satellites. Meteors can reach speeds faster than bullets, 42 kilometres per second (26 miles per second). At these rates, even small space rocks can pierce a hole in a weak part of a satellite. Natural and human-made debris are real threats to any space hotel, which is why testing impacts during material test programs should be an essential part of any orbiting space hotel's creation.

: CORROSION:

This type of testing verifies lifespan before the material breaks down. Corrosion in space is the corrosion of materials occurring in outer space. Instead of moisture and oxygen acting as the primary corrosion causes, the materials exposed to outer space are subjected to vacuum, bombardment by ultraviolet and X-rays, and high-energy charged particles (mostly electrons and protons from solar wind). In the upper layers of the atmosphere (between 90–800 km), the atmospheric atoms, ions, and free radicals, most notably atomic oxygen, play a major role. The concentration of atomic oxygen depends on altitude and solar activity, as the bursts of ultraviolet radiation cause photodissociation of molecular oxygen. Between 160 and 560 km, the atmosphere consists of about 90% atomic oxygen. Corrosion in space has the highest impact on space hotel with moving parts. Early satellites tended to develop problems with seizing bearings. Now the bearings are coated with a thin layer of gold. Different materials resist corrosion in space differently. For the example, an aluminium is slowly eroded by atomic an oxygen, while gold and platinum are highly corrosion-resistant. Gold-coated foils and thin layers of gold on exposed surfaces are therefore used to protect the space hotel from the harsh environment. Thin layers of silicon dioxide deposited on the surfaces can also protect metals from the effects of atomic oxygen; e.g., the Starshine 3 satellite aluminium front mirrors were protected that way. However, the protective layers are subject to erosion by micrometeorites. Silver builds up a layer of silver oxide, which tends to flake off and has no protective function; such gradual erosion of silver interconnects of solar cells was found to be the cause of some observed in-orbit failures.

: COMPRESSION:

Compression strength is vital for materials destined to experience the extreme pressures of space. compressive strength or compression strength is the capacity of a material or structure to withstand loads tending to reduce size. In other words, compressive strength resists compression (being pushed together), In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analysed independently. Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures. Compressive strength is often measured on a universal testing machine. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

: FATIGUE:

Space hotel undergo intense stresses, and fatigue testing looks at how long the materials will last under the worst forces until they fail. "Metal fatigue" redirects here. For other uses, see Metal Fatigue (disambiguation). In materials science, fatigue is the initiation and propagation of cracks in a material due to cyclic loading. Once a fatigue crack has initiated, fatigue grows a small amount with each loading cycle, typically producing striations on some parts of the fracture surface. The crack will continue to grow until it reaches a critical size, which occurs when the stress intensity factor of the crack exceeds the fracture toughness of the material, producing rapid propagation and typically complete fracture of the structure. Fatigue has traditionally been associated with the failure of metal components which led to the term metal fatigue. In the nineteenth century, the sudden failing of metal railway axles was thought to be caused by the metal crystallising because of the brittle appearance of the fracture surface, but this has since been disproved. To aid in predicting the fatigue life of a component, fatigue tests are carried out using coupons to measure the rate of crack growth by applying constant amplitude cyclic loading and averaging the measured growth of a crack over thousands of cycles. However, there are also a number of special cases that need to be considered where the rate of crack growth is significantly different compared to that obtained from constant amplitude testing. Such as: the reduced rate of growth that occurs for small loads near the threshold or after the application of an overload; and the increased rate of crack growth associated with short cracks or after the application of an underload.

FIG. 11: FATIGUE.

: MATERIALS WHICH ARE STRONG ENOUGH TO SURVIVE IN SPACE

: KEVLAR:

FIG.12: KEVLAR.

Kevlar is more frequently associated with its use in bulletproof garments for the military and police. This material has several properties that make it ideal for use in space hotel. It has strength enough to resist bullets, making it perfect for standing up to impacts from meteors and space junk. Additionally, Kevlar weighs little compared to its durability. It also can experience extreme temperatures without damage to its structure or changing its form. Kevlar is a material extensively used for the design and manufacturing of the shields protecting the manned elements of the International Space Station (ISS) from the threat posed by meteoroids and space debris that increasingly pollute the Earth orbits. Kevlar has been also selected for extensive use in the manufacturing of innovative flexible structures under development for future manned exploration missions. Kevlar initial selection was due to its excellent ballistic properties for debris shielding, but its compatibility with the space environment had to be thoroughly assessed. In parallel to hypervelocity impact tests, to quantify its capabilities to reduce space debris lethality, a significant amount of analysis, testing and simulations was performed to understand and characterise the behaviour of Kevlar in space environment conditions.

: ALUMINIUM:

Another common material used in space hotel is aluminium. Though itself, aluminium does not have the needed strength for space use, when combined with other metals into an alloy, its strength increases while maintaining its signature light weight. Aluminium alloy performs so well in impact testing that the International Space Station uses this material for its window shutters to keep debris from damaging the windows. Aluminium combines characteristics of pre- and post-transition metals. Since it has few available electrons for metallic bonding, like its heavier group 13 congeners, it has the characteristic physical properties of a post-transition metal, with longer-than-expected interatomic distances. Furthermore, as $Al3+$ is a small and highly charged cation, it is strongly polarizing and bonding in aluminium compounds tends towards covalency; this behaviour is similar to that of beryllium ($Be2+$), and the two display an example of a diagonal relationship. The underlying core under aluminium's valence shell is that of the preceding noble gas, whereas those of its heavier congener’s gallium, indium, thallium, and nihonium also include a filled d-subshell and in some cases a filled f-subshell. Hence, the inner electrons of aluminium shield the valence electrons almost completely, unlike those of aluminium's heavier congeners. As such, aluminium is the most electropositive metal in its group, and its hydroxide is in fact more basic than that of gallium.

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FIG. 13: ALUMININUM.

: REINFORCED CARBON-CARBON COMPOSITE:

For the nose of the space shuttle that encountered temperatures over 1,260 degrees Celsius (2,300 degrees Fahrenheit), NASA used a reinforced carbon-carbon composite (RCC). Other areas of the space shuttle that experienced similarly hot temperatures used this composite. the benefit of RCC lies in its ability to give off heat applied directly to it as well as indirect heat. The warmth from nearby surfaces on the shuttle travelled to the RCC-covered parts, where the RCC would release the heat, helping the shuttle to cool down, similar to the way a radiator indirectly cools a car engine. The process used to create RCC created cracks when the designers applied silicon carbide coating at high temperatures. However, when the temperatures around the shuttle rise, the cracks close. This changing of the material's structure at various temperatures iterates how necessary testing the content is. Without thorough examination, a part made of RCC or similar composure may not perform as expected at elevated temperatures, causing the failure of the piece and the space hotel it's part of.

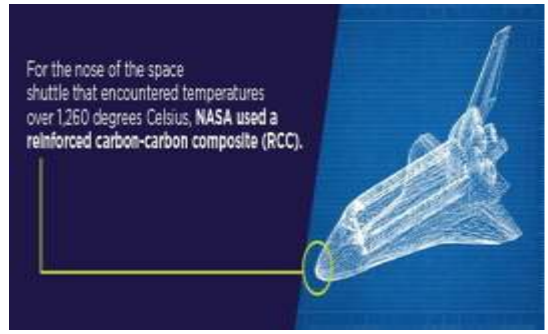

FIG. 14: REINFORCED CARBON-CARBON COMPOSITE.

EXTERNAL AND INTERNAL STRUCTURE AND CONSTRUCTION PHASES

No taller than 122 m, nor wider than 180-190m, Cicada is a small habitat, which resonates quite well with its name. It is designed to meet the characteristics of one of the first hotels in space. Its main goal is to help unleash the development of space tourism and space industry as a whole, eventually accommodating the general population with the idea of space travel and encouraging investors to further fund the construction of future self-reliant space settlements, with a greater magnitude and population sustainability. In what follows, among others, we will calculate the values of the projected area and habitable volume of each component of the spacecraft projected area is defined as the area dedicated to the construction of buildings for the general population. The projected area belongs to a plane perpendicular to the direction of pseudo-gravity. Additionally, the habitable volume represents the volume in which the variation of the artificial gravity is not greater than a given value, Δ g; thus, this volume depends on the Δ g/g ratio. Both the projected area and the habitable volume influence the density of the population. Because artificial gravity is induced as a result of rotation, there are not many alternatives for shapes. A three-dimensional shape viable for such a structure should be obtained by rotating a closed, smooth curve around an axis (which is actually the central axis of the settlement). Preferably, this two-dimensional shape should also be double symmetric. Such shapes are the sphere, the torus, the cylinder, the double cylinder, the dumbbell and others obtained by combining or altering them.

: FIRST FLOOR:

The first floor has approximately half the projected area of the second one but is characterized by a greater value of pseudo-gravity, which is 0.6 g. Therefore, we have established that we would locate the hotel's headquarters here, which include the employee dormitory. Other area locations will be represented by a shopping district, a food district, a small medical facility, food processing centres and a casino. Given the total 15-meter height, it is possible to separate the hotel and employee dormitory into 3- 4 levels and others into 2 levels (when applicable; mostly for closed areas, like restaurants and shops). Aside from working as a method to save space, if done correctly, this can also visually enhance the aspect of the park and add diversity to its range of attractions. The remaining area that is not occupied by buildings will be used as a relaxation/strolling area, filled with paths, benches and greenery in genera. Transport routes connecting the intermediate double cylinder to the hybrid torus as well as the two levels of the hybrid torus, are separated into two categories; thus, there is an elevator for cargo and one for people, each passageway with a maximum diameter of 8 meters (the height of the intermediate double cylinder). An additional green area, separated into more levels the circular side walls (generated by the torus component of the hybrid cylinder) and will generally work as a hydroponics plantation.

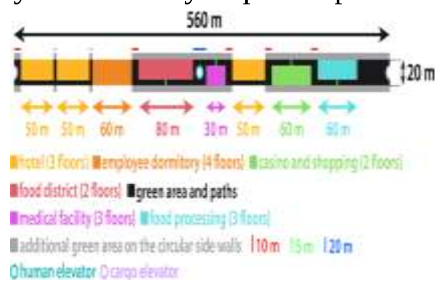

Fig.31:(Area Allocations On The First Floor Of The Hybrid Torus; Note That The Green Area Across The Employee Dormitory And Hotels Is Only Represented By The Fourth Level Of The Agricultural Sector)

: THE SECOND FLOOR:

The second floor is considerably more spacious and features a maximum artificial gravity of 0.5 g. If the first level has the floor separated into a toroidal component and a cylindrical one, the second level has an identical configuration, but for the ceiling. The width of the park comes close to 50 meters (it is not exactly 50 meters, because a portion of the ceilings circular and, for a small distance, does not allow a minimum height of, say, 3 meters, enough for a person to pass through without having to bend); we take into account this approximate value (note that certain buildings will be built with circular exterior walls, mostly covered in windows, facing the part of the hybrid torus also covered in windows). The length of the second-floor length is approximately 470 meters; given the reduced overall dimensions of the habitat, this is not quite as cramped as expected at a first glance. We plan to create a small water park as part of the amusement park, with a length of 150 meters and a width of 40 meters. This would consist of a large pool, perhaps separated into age categories, but also a number of slides and jumping platforms alongside the gravity gradient (which goes up to a minimum value of roughly 0.4 g, right where the ceiling is). A second level can be added as a sort of balcony, to include one or more jacuzzi hot tubs and a SPA centre.

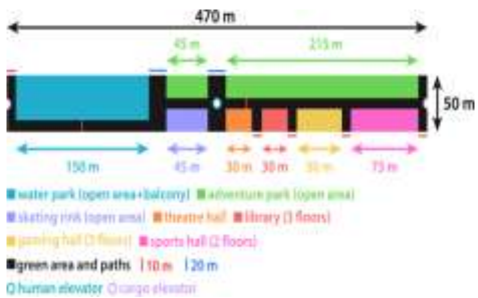

Fig.32: (Area Allocations On The Second Floor Of The Hybrid Torus) (Note That There Is Some Unrepresented Space Between Buildings And The Settlement's Hull)

: THE HOTELS:

These hotels are placed on the first floor of the hybrid torus and have a length of 50 meters and a width of 15.5 meters. It can be considered a small hotel chain, consisting of three separate hotels: Agon, Alea and Ilinx (terms which stand for categories of games defined by Roger Caillois in "Man, Play and Games", as we discussed in our introduction). Each one of them is separated into three levels, the last two being 3 meters tall and the first one being 4 meters tall, given that the lobby is also located there and should be more spacious (therefore a hotel is 10 meters tall). Their structure is identical, for the most part, each of them having a number of 4 suites, 68 double rooms and 8 single rooms; thus, there are a total of 80 rooms per hotel and, if we consider that a suite has an average capacity of 3 people, we conclude that each hotel can accommodate around 156 tourists, perhaps even more. Therefore, the settlement's maximum (and final) capacity, if we exclude staff, would be around 468 tourists. We plan to build the hotel chain as a two- phase process, gradually increasing the habitat's capacity, firstly building one of the hotels and then the next two. The circular side walls on the first floor will be used for agriculture. However, the first three levels of this agricultural area will be eliminated from the portions of the circular side walls in the front and in the back of the hotels and employee dormitory and replaced with windows. This is because tourists and short-term residents should be able to look out the window from their room and admire the otherworldly scenery provided by the location. The fourth level will remain, since these buildings are not tall enough to reach it.

: CONSTRUCTION PHASES:

: PHASE 1:

Phase 1 ends when the construction of the first part of the settlement reaches completion. This means that the dock, the central sphere, the intermediate double cylinder and the hybrid torus are all built during phase 1. In total, in order to be able to build the entire structure, not taking into account the internal mass and the mass of the atmosphere for the pressurized modules, around 60 launches would be required. That is, if the rocket used to transport cargo and people into orbit has a capacity of at least 50 metric tons; Falcon Heavy, developed by SpaceX, can carry around 53-54 metric tons worth of payload into the Low Earth Orbit, thus earning its title of "the world's most powerful rocket" After the first launch, a small cylindrical structure will be taken into orbit, along with EVA equipment and a portion of the solar array linked to the central sphere (this portion represents a circular crown with radii of 30 and 34 meters; the final solar array is a circular crown with radii of 30 and 38 meters). This cylinder has a height of 14 meters and a radius of 7 meters; in a more advanced stage of construction, it will serve as a passageway between the central sphere and the dock (note that this passageway is only 4 meters long, but another 10 meters can be added from the dock's height). The cylinder will be endowed with 3 docking ports and GN&C and P&MC systems (whose location will be changed after the central sphere is built); it will mainly function as a base, until the construction of the central sphere is completed. Approximately 7 launches would be needed to build the central sphere along with the components of the Maglev rotation mechanism and the complete central solar array. The materials needed to build the intermediate double cylinder can be brought into orbit after roughly 11 launches at this stage, a larger crew can start inhabiting the settlement, given that artificial gravity will be present. 3 additional launches are required to add the dock to the construction. Finally, as the major component of the habitat, the hybrid torus will require 39 launches. Launches required to build a certain component may overlap with others, since they represent approximate values. Thus, the sum of these values may be higher than the required number of launches for the entire first part of the settlement. 8 launches are required to transport gas tanks into orbit, for the pressurized modules. As far as the internal mass is concerned, phase 1 will be separated into 2 stages of construction; Cicada will reach the end of the first stage of construction once it is able to accommodate 200-220 inhabitants (this stage of construction corresponds to the construction of Agon, the first out of the three hotels, presented in Sub-chapter. This requires 169 launches, in total. The second stage of construction, with a maximum and final capacity of around 600 inhabitants) will be completed after 177 additional launches and will be finalized once the other two hotels, Alea and Ilinx, are built. Time periods for these two stages are difficult to predict, because they are easily influenced by a multitude of factors. Profits obtained during stage 1 will indicate the beginning of stage 2. Technical development for reusable launch vehicles and other space-related technologies should also be taken into account.

PHASE 2:

The second part of the settlement will be built during phase 2: the column, the small sphere and the torus. Whether phase 2 will take place in the near future or somewhere further along the line depends on the profits obtained during phase 1, but also on technological progress. Around 35 launches are required for phase 2 to reach completion, if internal mass is taken into account. The construction of the column requires roughly 2 launches for its shield and rear wall, as well as the atmosphere inside. For the same purpose, the small sphere only requires one launch and the torus (together with its spokes) requires around 13 launches. The remaining 19 launches for phase 2 are for the internal mass.

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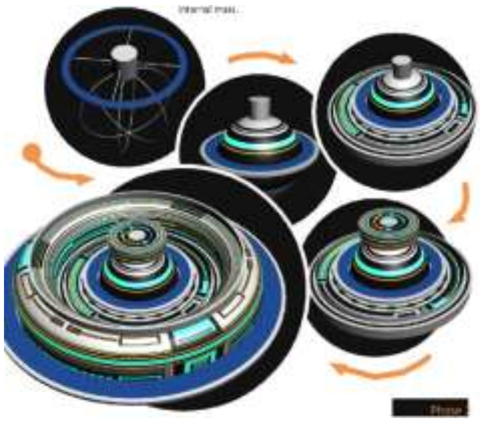

FIG.34: CONSTRUCTION 1& 2 PHASES

IV.CONCLUSION

Certainly, in the beginning of space tourism, the target market will consist of extremely wealthy individuals. What can be concluded from all the surveys is that space tourism is perceived as a great enhancement to the evolution of humanity and is intriguing and fascinating to many; however, not all of these enthusiasts are able to afford such a trip, at least not for the time being. Most of the surveys were mainly concerned with orbital/ suborbital flights; in the case of a space hotel, it can be assuredly stated that a great majority of those who are willing to pay for and experience an orbital flight would also be interested in a stay at a hotel, for which the price could be considered an irrelevant addition to the enormous transport cost (especially if artificial gravity is provided). What is also noticeable is an expected recurring concern for safety, which arises from the risks associated with our current means of traveling to space and inhabiting it; many regard absolute safety as currently unrealistic and are willing to wait until this is proven otherwise to even consider embarking on a journey to space. Fortunately, one prediction for the future is that technological development and more experience in this field of industry will cause a significant drop in prices and will provide much safer conditions for trips to space, therefore further enlarging the size of the target market; one of Cicada's main purposes is to act as a starting point and lead us towards a future of that kind and, hopefully, far beyond.

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