Preparation for a Commercial Space Station

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ABSTRACT

The International Space Station (ISS) has served the world in a variety of ways, even early in its development. This report develops how to use the information gathered from the ISS and apply it to the creation of a commercialized space station. This will be the first step towards the colonization of space. The ISS is used as a guide indicating which components of a space station are necessary. This report also considers possible products for a commercial station and analyzes the viability of these options. Finally, the effects (of developing a colony in space) on humanity are discussed. This project may serve as a guide for future endeavors into the colonization of space.

EXECUTIVE SUMMARY

The following project was undertaken in order to develop a number of aspects related to the colonization of space. Specifically, the project focuses on how to use the International Space Station (ISS) as a guide to follow for placing into orbit a commercialized station eventually capable of housing a community, producing an income for its owners and establishing a precedent as a business-minded orbiting facility with human inhabitants.

After a description of the ISS, a two commercial possibilities for development are discussed along with some secondary ideas. The primary possibilities are Aerogel manufacture and organ tissue growth. Other mentioned ideas include Laser Crystals, Computer chips, Protein Crystals and the possibility of a commercial research laboratory available for leasing by the scientific community.

The two primary possibilities, Aerogel and organ tissue are grossly different in use and therefore differ in their design. Through a thorough analysis, this report presents the feasibility of each of these options. Brief estimates of the budgets for the proposed stations are considered to aid in the conclusions. The conclusions are that currently, the commercialization of space is not feasible. Both Aerogel and organ tissue production have potential for future applications of space. Unfortunately,

at this time the costs associated with space manufacture are greater than the possible gains.

Of the two options considered, however, it was found that organ tissue growth has the most potential for future use in space. There is a well-established market for organs for transplantation and the costs associated with this are already quite large and would more easily facilitate production in space.

Further discussion studies the impact that the commercialization of space would have on society as a whole. Social, political and economic aspects are considered in this section. Many ideas are presented which question how life in space would exist. This section is forward looking to a time when space is fully colonized to the point of births occurring in orbit. The raising of children in this environment presents an interesting basis for thought. Many other aspects of human-life need to be discussed in order to prepare for the possibilities that the future presents to humanity. This project attempts to begin this discussion and generate some thought into subjects previously uncovered or of little earlier development.

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CHAPTER 1 - INTRODUCTION

Throughout history, mankind has explored the area around him. This has progressed across large landmasses, oceans, ice covered landscapes and now even into outer space. With this recent progression come some new questions to consider. Is space a suitable landscape to send out the next colony? And if so, how must it be accomplished? The author of this paper feels space is a suitable step that must be taken. Earlier explorations of our own planet have always had a high level of risk and possibilities of death. However, at this point there are few parts of the world that have been untouched by the human hand. Space is the next step in humans' natural progression.

Besides the idea of space being a natural step into the unknown, there is the idea of self-preservation that must be considered. The world we live in is by no means safe. There are many opportunities for the collapse of this planet. We all know that eventually Earth will no longer be able to support our fragile life support system. Planets were found to drift farther from the sun, a major source of life on Earth. Also, other environmental problems, such as the erosion of the ozone layer, which protects us from solar radiation, support further the idea that the ecosystem of the Earth will eventually collapse. However, all of these ideas seem in the far-off future, with little impact on our own lives.

In the more immediate future, there are also situations that pose a threat to our way of life. This can be seen in many ways. There is always the chance for a nuclear war, where mankind itself would destroy the planet. Also, an asteroid might strike a path towards our fragile planet that could obliterate the planet or just a large portion of it. There is also the impact of diseases that could develop so rapidly as to significantly decrease Earth's population.

Due to these and many other reasons, it is the author's opinion that the colonization of space is at the very least an option that humanity should naturally investigate as a matter of course. A self-supporting space colony would be unaffected by any disaster that occurred on Earth, thus allowing for further survival of mankind. Based on our own self-preservation alone, space colonization is a necessity for our future and the continuation of the human race.

For obvious reasons, however, the colonization of space is a bit more involved than designing a ship and navigating across an unknown ocean of water, although there are many similarities. Just at Queen Elizabeth funded Christopher Columbus' famous journey across the Atlantic from Spain, so has every great feat of exploration had a person of high authority backing the project and generating the funding. The most famous of these, in recent times, was by President Kennedy in 1961 as he addressed Congress and gave his famous speech:

> I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish.[1]

Financing a project of such magnitude as creating a colony in space is no small task by any stretch of the imagination; this is easily seen in the International Space Station's growing budget problems, where the cost was initially projected to be $17.4 billion and has now ballooned to $30.1 billion projected through fiscal year 2006.[2] Although this is primarily a research facility, it's sheer size approaches the necessary size for the first small colony leaving our planet. Along with the financing, there would be an enormous amount of red tape by government restrictions and approval to produce such a project.

To date, no company outside of the government has put a man or woman into orbit or has the facilities to do so. So, whether the government succeeds or a company in the private sector, it will not be a simple task.

The many difficulties of space colonization include how to create an ecosystem in which a living society could be sustained independently of Earth. Finding a location for this new society would be a difficult decision

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[1] John F. Kennedy, "Urgent National Needs", 25 May 1961
[2] IMCE Report to NASA Advisory Council, November 1, 2001.

also. Humans need a number of elements that are vital to their survival besides just a shelter, such as breathable air, water, nutrients, vitamins, minerals, sunlight, medicines, etc. Currently, there are a number of places discussed as possible destinations; the Moon, Mars, Venus, a near Earth asteroid, or a space station like structure placed in orbit. All of these ideas and many more are valid, but they all come with their own shortcomings and difficulties in sustaining life.

Another widely publicized difficulty arises in how to get where we want to go. Once we determine our destination, we need to develop the means to get there. Currently, our mode of transport for Americans is the Space Shuttles, which have a range of 185,000 to 643,000 kilometers.[3] Mars is, at least, 56 million kilometers[4] away, while the moon is much closer at 384,401 kilometers[5]. In order to truly speculate on colonizing celestial bodies of a greater range, a new propulsion system will need to be developed, as our current means is merely too slow and unacceptable.

The author of this paper feels it is required to first understand the harsh reality that the colonization of another celestial body or man-made satellite in a permanent state is no simple task. After realizing that, we are able to continue to start the development process. In actuality, the development of such a mission has already begun through the studies

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[3] http://www.spaceflight.nasa.gov/shuttle/reference/shutref/sts/profile.html
[4] http://solarsystem.nasa.gov/whatsnew/pr/010613B.html

conducted in the past and research currently being conducted. This study will focus on one avenue for the establishment of a space bound colony. It is our contention that while the government is the only organization seemingly large enough to incorporate this project into their research and goals, it will take the commercial world to pursue and actually send out the first colony. This project will be an early look at the possibilities a company would have when considering the move to space. Commercial industry has already begun in space, in the area of satellite communications. Through this groundwork, the legal issues in reference to the FAA and similar government agencies will have to wait until the laws governing such an act of privately sending humans into orbit are in place. However, until then this project will look at the precedent set by the International Space Station (ISS) as a permanent establishment in space. From the information compiled concerning the ISS, a few ideas will be generated concerning possible commercially viable reasons to go to space, how to get there with a smaller budget than was established for the ISS and the results affecting society from this leap into space.

It is only natural that a space station would be chosen as the first step into space. A natural progression deeper into space could eventually be established through orbits of ever-increasing diameter. A space station would first be created in Low Earth Orbit (between 350 and 460

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[5] http://nssdc.gsfc.nasa.gov/planetary/factsheet/moonfact.html

kilometers). However, space stations could eventually spread to higher orbits, eventually creating a path of small stepping-stones upon which far-off planets could be reached.

As previously stated, this project will focus on the first primary step that needs to be established. That is at the level of LEO in the creation of a functioning space station, necessary for allowing deeper space penetration through a more distributed means of resources. Throughout this paper it is important to keep a few things in mind regarding the ISS. The ISS was primarily devised by the government and, therefore, has an entirely different purpose. The ISS was established as a research laboratory in space as opposed to either a business idea for creating revenue or as a step towards space colonization.

This paper will start by detailing relevant background information concerning the ISS. It will show the history of its development, how its design has changed over the years and the resulting research that has been already generated from this facility along with current and future research plans. Details concerning the budget allotted to the ISS will be presented and how this money is being allocated throughout the project.

Continuing on in the proposal will be the description of the proposed space station as a commercially funded project designed for the purpose of a) generating revenue and manufacturing or selling a product, and b) establishing a stepping stone through which access to the rest of space is granted. This section will detail the possible commercial opportunities for the station along with an analysis of the possibilities. Also, details concerning the budget of the new station will be discussed, primarily the idea that through commercialization, costs can and will be cut in mass quantities. While the costs of such a station will still be large, the right corporation with the right interests in mind would be able to complete such a task.

The next section will be an analysis of the affects to society produced by such a venture into space. This section will attempt to brainstorm ways in which this station could affect the social, economic and political aspects of our society. The social aspects will most directly study the effects of a society that lives in micro-gravity and how that would change the day-to-day routines that are taken for granted on Earth.

Finally, a summary of all of these ideas will be presented in the final conclusion section. Also, presented here will be an analysis of the ideas along with recommendations for further studies.

CHAPTER 2 – THE INTERNATIONAL SPACE STATION

INTRODUCTION

This section is an introduction to the International Space Station, its purpose, function and history, in order to first understand how this engineering marvel can be applied to the topic of space colonization. These are two relatively separate realms of space exploration, but have many links that tie the two together. The basic design elements are similar as are the construction and implementation. The major design differences lie in their inherent differences in aspirations. However, the many similarities allow the ISS to serve as a guide for a commercial space station.

ISS - BRIEF HISTORY

The International Space Station has a much longer history than most people are aware. The idea was initially conceived in the late 1960's and early 1970's. The first space station was actually launched by Russia in April of 1971. It was called the Salyut and was the first of six stations under the same name. In May of 1973, the United States joined in the exploration into creating a space station. The first U.S. station was called SkyLab. During operation, SkyLab was host to three different space crews before ending its career in February of 1974. Since then, the most successful and longest-lived space station before the ISS was MIR, a Russian station, launched in February of 1986 and brought to dramatic ending, mostly burning in the atmosphere as it was pulled out of orbit on February 28, 2001.

In 1988, the United States decided there was a need to develop a new space station. Then president, Ronald Reagan, named the proposed space station *Freedom*. However, subsequent funds from the federal budget were re-allocated from the space station, making it difficult to maintain the development and design schedule. As the space station's details developed, so did the needed budget. As a result of the increasing costs and design complexity, President Bill Clinton called for a revision of the station in 1993. The new design called for international cooperation and support to ease the burden on the United States budget. It also allotted locations for other countries to mount research laboratories and participate in the construction of the entire station.

A number of countries joined the effort to erect what will become a place in orbit that will allow ongoing experimentation. Ultimately, the ISS will provide a place for shuttles to dock and refuel while en route to other locations, allowing for greater distances to be covered by shuttle missions. The ISS will also enable countries with underdeveloped space programs to conduct experiments in the harsh environment of space. As of now, the main components to be placed on the ISS will be supplied by the United States, Russia, Europe, Italy and Japan.[6]

The ISS, as originally scheduled, would have been fully completed in 2006. However, more budget problems arise seemingly yearly and again in 2001, there was another call by Congress to pull back the reigns on the design and construction of the ISS. In response, NASA's engineers have presented a newly designed goal for a new "complete station". This has mostly involved holding back on some of the elements that were originally designed into the project. These are the Habitation Module, the Propulsion Module and Crew Return Vehicle.[7] These components will be detailed in the following paragraphs. The new scaled down version of the

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[6] http://www.spaceflight.nasa.gov/

[7] http://www.hq.nasa.gov/congress/goldin4-4.html

ISS is called "Core Complete" and is designed to provide NASA and the world with a space station that allows for the most essential ingredients of a space station, namely, research. NASA has pointed out that while these elements have been removed from the "Core Complete" form of the ISS, they are holding on to the extra components for future use if the opportunity ever arose.

Regardless of the minimization of the station, the ISS will inevitably be a spectacular engineering marvel with benefits to a large number of fields and enabling future space exploration. The sheer size of the station and its components is an engineering feat of great proportion, without factoring the effects of building such of structure in a vacuum and a micro-gravity environment. Upon completion, there will have been over forty trips to the ISS, bringing supplies, crewmembers, and various parts for construction. These trips will be accomplished using the U.S. Space Shuttle, the Russian Soyuz rocket, and the Russian Proton rocket. The station itself will be inspiring, weighing approximately one million pounds (460 tons) with a volume of 43,000 ft^3. It will generate 110 kW of power through sixteen solar arrays, composed of four pairs of US arrays on the central truss system and four pairs to power the Russian-owned components. Each U.S. solar array alone is the size of a Greyhound bus and combined the ISS could cover the area of a football field, including the end zones. With the addition of the CRV, the station would be capable of supporting up to seven crewmembers.[8]

Some orbital information regarding the space station is of importance also. During the development of the ISS, the orbital parameters have been amended. Originally, when the ISS was simply an American endeavor, the orbit track covered less area. However, when Russia joined as a major contributor, this was changed to enable extended Earth coverage (primarily to reach areas of northern Russia). The current orbit has been designed to cover 85% of the Earth's surface area and in doing so passes over 95% of the Earth's population. This has been done through an orbit that is at an altitude of 350-460 kilometers and an inclination of 51.6 degrees to the equator. The peaks of the orbit reach 52 degrees north and south latitude.

In order to stay in this orbit it is necessary to have periods of "Reboost" as the ISS's orbit decays due to atmospheric drag. A short explanation of this phenomenon is provided. While the ISS is at an orbit that is clear of most of the Earth's atmosphere, there is still a small amount that causes a drag force and resultant orbital decay. Further decay results from the ISS's occasional passes through the Van Allen radiation belts, which are commonly avoided by most spacecraft. These radiation belts vary in intensity, but nonetheless cause a significant

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[8] http://www.spaceflight.nasa.gov/

amount of drag to the space station. The large cross-sectional area is also detrimental to the station's orbit. The Reboost period occurs every 10-45 days and lasts for only one or two orbits. Each orbit is roughly one and a half hours in duration. This recovers the lost altitude of roughly 0.2 kilometers per day. It is important for scientists to be aware of this Reboost period, as it temporarily affects the micro-gravity conditions aboard the station.[9]

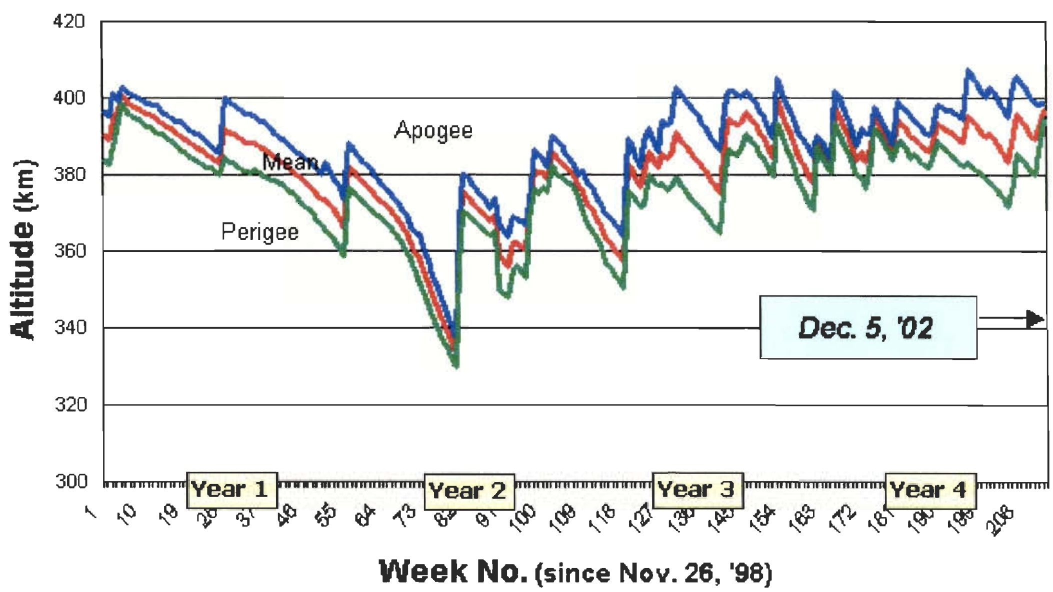

Figure 1: ISS Altitude History (Courtesy of NASA -Headquarters)

[9] International Space Station User's Guide

ORBITAL DECAY DESCRIPTION

VARIABLES

Gravitational Force	$= F_g$
Centrifugal Force	$= F_c$
Drag Force	$= F_d$
Coefficient of Drag	$= C_d$
Density of air	=
Cross-sectional area of ISS	= A
Mass of Earth	$= M_e$
Mass of ISS	$= M_{ISS}$
Gravitational Constant	= G
Velocity of ISS	= V
Distance from center of Earth to ISS	= d

EQUATIONS

$F_g = (G*M_e*M_{ISS})/d^2$

(This is the force exerted on the ISS by Earth, pulling the ISS towards Earth.)

$F_c = (M_{ISS}*V^2)/d$

(This is the force felt by the ISS due to its momentum, pulling the ISS away from Earth.)

$F_d = {}^1/_2 C_d* \; *V^2A$

(This is the force opposing the forward motion of the ISS, slowing down its velocity.)

ANALYSIS

In order for the ISS to maintain its altitude, the force of gravity must equal the centrifugal force. This results in the following conclusion.

$F_g = F_c$

$(G*M_e*M_{ISS})/d^2 = (M_{ISS}*V^2)/d$

This simplifies to:

$(G*M_e)/d = V^2$

The gravitational constant and the mass of Earth are constants, therefore for a given altitude; the velocity of the ISS can be calculated. From the data on the ISS, we have the altitude varying from 350 – 450km, roughly. For an example, we'll assume the ISS's altitude to be at 400km.

$G = 6.67 \times 10^{-11}\ N{*}m^2/kg^2$
$M_e = 5.98 \times 10^{24}$ kg
$d = 6.8 \times 10^6$ m

From these values, the velocity of ISS becomes: V = 7658.77m/s

The atmospheric drag forces exerted on the ISS however cause the decay of the orbit. From above it can be seen that the drag force depends on a number of variables: drag coefficient, density of the atmosphere, velocity of the ISS and the cross-sectional area of the ISS. The drag coefficient depends on a number of variables, such as atmospheric conditions, velocity and reference area. For the ISS the conditions result in a net decay of 0.2 kilometers per day. This translates to 0.0023 meters per second. This may seem small, but becomes significant over time. To analyze the drag force, we first look at the two equations that directly affect the movement of the ISS towards or away from Earth.

$F_g = (G{*}M_e{*}M_{ISS})/d^2$

$F_c = (M_{ISS}{*}V^2)/d$

As previously stated, when these forces are equal, the ISS stays in one orbit. However, the drag force on the ISS results in a decreased velocity over time. The result of this drag force is a lowered centrifugal force. Therefore, Earth's gravitational force outweighs the centrifugal force :

$F_g > F_c$

The result of this is a net force on the ISS towards Earth and a subsequent decay in its orbit.

ISS COMPONENTS

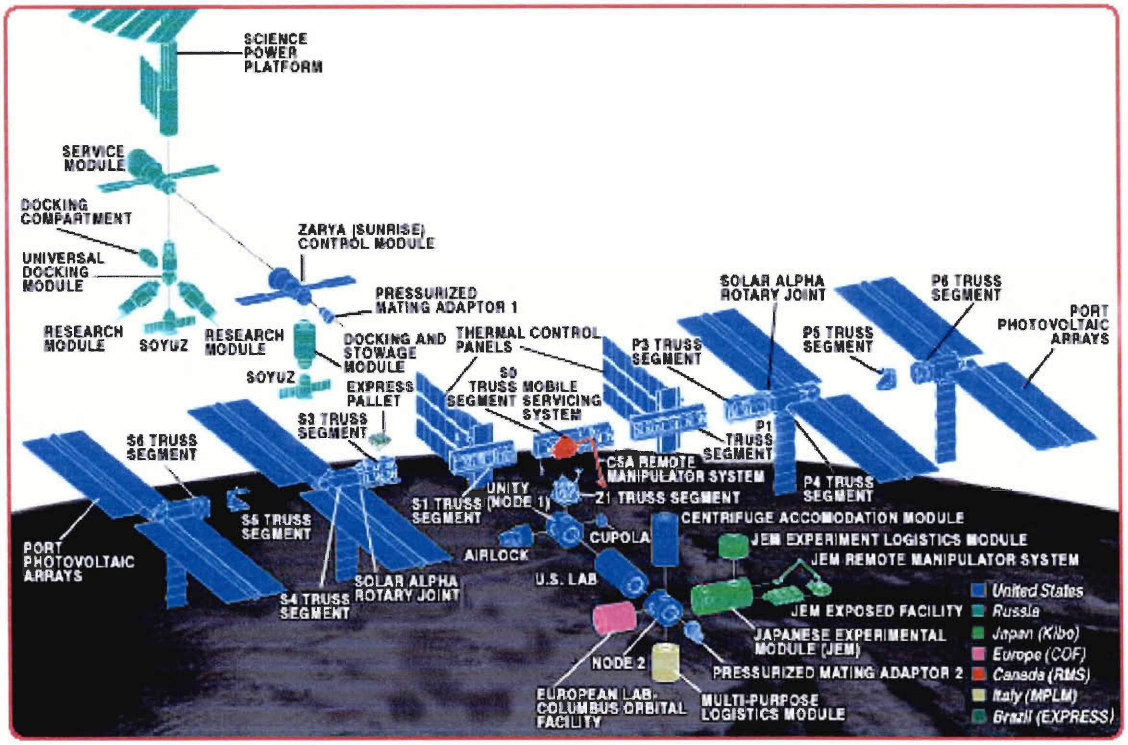

Figure 2: Exploded view of the International Space Station with individual components labeled. (Courtesy of www.spaceflight.nasa.gov)

Obviously, the ISS has many components, many of which could be removed for the purposes of creating a space station with a design directed towards manufacturing. This section will explore the components that make up the ISS, and then each part will be analyzed for its value in a newly created space station. After deciding which parts are needed and which can be omitted, it will be necessary to look at which components need to be added to the product specific space station.

The following is a brief description of all the major parts aboard the ISS, starting with the elements added by the U.S.

The initially most striking element of the ISS are the Solar Arrays and the Truss System that holds all of the pieces together. The Solar Arrays are responsible for providing power by harboring solar energy captured from the sun. The Truss System attaches the Solar Arrays to the main hardware in the ISS. Each piece of the truss system is named for its position on the system, grouped by Starboard, Port or Z-axis locations. The Truss System is actually very advanced providing two modes of rotation to ensure maximum exposure to the sun. Also, it houses much of the hardware to convert the energy to useful power (which incidentally, provides 110KW of power). Three of the nine truss segments have been added to date, the Z0, S1 and P1.

The Mobile Servicing System is the base for the Space Station Remote Manipulator System (SSRMS), which will be described later. It serves to attach the SSRMS to the Truss System.

There are a total of three “nodes” on the ISS. The first is called “Unity” or simply, “Node 1”. Each of the three nodes has one task in common. They are responsible for connecting various components of the ISS. Along with this, they also provide other uses. Unity’s extra purpose is merely for extra storage space, while connecting the U.S. Lab to the Airlock, Cupola, Node 3 and Z1 Truss Segment.

Node 2 connects the U.S. Lab to the laboratories supplied by Europe and Japan and docking locations for the Pressurized Mating Adaptors (PMA) and Multi-Purpose Logistics Modules (MPLM), while providing a location for equipment racks necessary for converting electrical energy for use in the surrounding laboratories.

Node 3 connects Node 2 to the Crew Return Vehicle, Habitation Module and PMA-3 while providing a location for life support equipment.

In order to accommodate extra-vehicular activity (EVA) there must be a point of egress. This is provided on the ISS through the “Airlock”, which is designed for use with Russian and American space suits. The Airlock allows for exit and entry without losing air into space and also provides a changing room for astronauts to suit up and store suits.

The cupola is a rather simple room with windows on all sides that allow scientists to view astronauts involved in EVA’s and oversee the use of the SSRMS. The simplicity is lost when the pressure absorbed by the windows is considered. Keep in mind that the pressure inside the ISS is kept at atmospheric pressure, while outside there is a vacuum. This results in a large force exerted on any structure in space. Placing windows on orbital facilities is especially difficult to facilitate safely. For a simple one square foot window, the force exerted on it becomes the equivalent of 2116 pounds. To relate this to windows found on Earth, we look at “Krinklglas®”. This product is touted for being “virtually unbreakable", a "unique, invisible fiberglass reinforcement makes panels impact resistant and shatterproof...much stronger, lighter and safer than glass. KRINKLGLAS® can withstand impact from such objects as projected stones, bricks and bottles without shattering." However, when its physical properties are reviewed, it displays a static load capability of only 480 pounds per square foot.[10] This may be high quality for Earth but would be deadly in space. In order to be a safe window in space, the material would need to be capable of withstanding a load higher than the normal load experienced by the window. In other words, it would not only have to withstand the normal 2116 pounds per square foot but a load higher than that to establish a suitable factor of safety. In space, factors of safety are commonly quite high, between 5 and 10. This results in the development of a window capable of sustaining loads up to 21,160 pounds per square foot! In order to accomplish this, the cupola will be outfitted with fused silica and borosilicate glass windows.

The U.S. Laboratory is the U.S.'s main research laboratory, providing 24 International Standard Payload Racks (ISPR). ISPR's will be discussed in a later chapter along with more detail about the capabilities and use of the U.S. Laboratory.

The Centrifuge Accommodation Module (CAM) is another U.S. research laboratory, capable of varying gravitational effects from .0001g's

[10] http://www.krinklglas.com/tec-data.html#csi

up to 2g's, through the use of a centrifuge. This will also be discussed in more detail later.

The Habitation Module, described in further detail in the section characterizing the components removed for the "Core Complete" or reduced design for the ISS. In short, this piece provides a housing environment for astronauts living on the ISS.

There are three Pressurized Mating Adapters (PMA), which allow docking locations for various un-crewed orbiters.

The Crew Return Vehicle (CRV) will be further described in more detail in the "Removed Components" section of this paper. In short, this component provides a means of emergency egress back to Earth for the seven astronauts aboard the ISS.

The Zarya (which means Sunrise in Russian) Control Module, Functional Cargo Block was the first element launched to orbit on November 20, 1998. This piece provided the initial logistical support for the creation of the ISS including orbital guidance control.

There are two large Thermal Control Panels (Radiators) attached to the Truss System. These panels are designed to rotate counter to the Sun to maximize the release of heat energy created through the use and conversion of the solar energy.

The main Russian Components are the Science Power Platform, the Service Module, the Docking Compartment, the Universal Docking

Module, two Research Modules, two Soyuz Rockets and a Docking and Stowage Module. These parts are described below.

The Science Power Platform was planned to provide power and control for the Russian portion of the ISS, while enabling rotation of the four attached pairs of solar arrays, which provide power to the Russian areas of the station.

The Service Module was the first Russian module sent to the ISS, initially providing living quarters, life support systems and other logistical support, such as the propulsion necessary for "reboost".

The Docking Compartment provides the airlock equipped solely for Russian use, as the U.S. space suits are too large to fit through the opening.

The Universal Docking Module is similar to the U.S.-provided nodes in that it allows for the attachment of four other modules.

The two Research Modules will serve as Russia's main laboratories, which are exclusive for Russia's research use. These are separate from the other research facilities that are shared by all other countries involved.

There are two Soyuz Rockets for transporting crews to orbit, one of which is docked at the station at all times (though rotated on a regular basis) as the crew's launch and return vehicle.

The Docking and Stowage Module is an additional stowage area for storing laboratory supplies and other essentials to support human life.

The rest of the major components come from a variety of sources, including Canada, Brazil, Europe, Japan and Italy.

The first of these is a research platform called "Expedite the Processing of Experiments on the Space Station (EXPRESS) Pallet" which is provided by Brazil. This component is attached to the Truss System for external research, directly exposing payloads to the space environment, allowing for research viewing the Zenith (away from Earth) or Nadir (towards Earth) directions. This allows for Earth observations as well as research concerning the Sun or stars in all directions.

The Space Station Remote Manipulator System (SSRMS) is Canada's contribution to the space station. It is a highly advanced 55-foot robot arm capable of moving up to 125 tons, but also with fingers (Special Purpose Dexterous Manipulator) for handling delicate components. This element is essential for piecing together the parts of the ISS and reducing the amount of extra-vehicular activities (EVA's) by astronauts. This increases the safety of the crews building the ISS. The SSRMS is also designed to work with the Space Shuttle's similar arm for removing components from the Shuttle's payload bay.

The Columbus Orbital Facility (COF) is a European-provided research laboratory, whose use is shared with the contributing countries.

There are three (Donatello, Raffaello and Leonardo) Multi-Purpose Logistics Module (MPLM) which have been contributed by Italy. They were developed for delivering pressurized experiments and hardware to the station, enabling experiments to be begun on Earth and delivered directly to the ISS minimizing the time spent for astronauts conducting the research. Each is capable of transporting 16 ISPR's at one time.

Japan has added the Japanese Experimental Module (JEM), a multifaceted research facility that has a number of smaller components. These are the JEM – Experiment Logistics Module (JEM – ELM), for stowage of experimental materials; JEM – Remote Manipulator System (JEM – RMS), which is similar to the SSRMS, used for placing external experiments; the JEM – Exposed Facility, comprised of two platforms enabling external research, similar to the other exposed experiment locations. [11]

[11] http://www.spaceflight.nasa.gov/

BUDGET

The budget of the ISS is a difficult topic to undertake. As previously stated, the ISS has been plagued throughout the years with cost overruns and budget cuts. This section will attempt to clearly identify the costs associated with creating the world's largest man-made orbital facility.

The problem that was encountered by the United States in regard to the ISS was over-simplification of the project. Just in design costs from conception in 1984 to the 1993 redesign, NASA spent $10 billion. Following that, the 1993 budget for the ISS construction was a mere $17.4 billion. After completion in June of 2002, the cost of research and operation of the station was to be $1.3 billion per year. Expecting to orbit until 2012, this brings the total cost for the ISS to $30.4 billion. This design made a number of assumptions that resulted in the major cost overruns that the ISS is now famous for. The primary faulty assumptions were that 1) the first module would be launched in May of 1997; 2) the Russians contributions to the station would save the U.S. $2 billion; 3) a heavy reliance on computer programs for designing and testing modules; 4) 500,000 source lines of code were expected to run the space flight software; and 5) de-staffing would occur as hardware was completed. Obviously, none of these assumptions were true. The first module was not launched until November of 1998, followed by a gap of eighteen months between the second and third modules. Russia was responsible for the delay of the launching of the third module (Zvezda) and thus rather than saving the U.S. $2 billion as assumed, they began a pattern of delays that has cost the U.S. billions.

Russia delays have resulted in the addition of the "Russian Program Assurance" into the U.S.'s ISS budget. This area of the budget is to provide a back-up plan for possible lack of cooperation by Russia. The result of this has been the additional design of an Interim Control Module and the Propulsion module, in case Russia fails to provide the Service Module and propellant logistics flights. The cost of Russian Program Assurance has risen steadily over the years to $1.3 billion projected through fiscal year 2006.

The next assumption, the reliance on computer software testing of designs was fractionally saved by the Russia delays. These delays gave NASA time to further test equipment that was ready for flight, according to the computer testing data. These tests resulted in the uncovering of problems that avoided the eyes of the software packages. This caused the development of an apt testing program, which also carried a larger price tag.

The expected lines of flight program code grew rapidly from the projected 500,000 up to the current projection of 1,500,000 lines of code, with 800,000 currently operational. The final result of the growth of the program and under-estimating of the necessary tasks to put the ISS in orbit has resulted in the failure of the final assumption; the need for staff has never dwindled.

The progression of the ISS has resulted in a rapidly increasing budget that can be portrayed in a number of ways. The following two graphs show a breakdown of the U.S. portion of the ISS budget for each year since 1994. (The values do not correspond to that year's budget, rather the projected budget over the life of the station.) The final bar in the first graph is the projected budget for the "Core Complete" version of the station. The first graph breaks that cost into a five groups, while the second graph displays the total budget costs. These groups are: RES, OPS, CRV, RPA, and VEH. RES stands for research and this portion of the budget is that which corresponds to how much money will be spent on actual research on the station. OPS stands for operations capability, which accounts for the costs associated with operating the ISS. CRV is short for Crew Return Vehicle, described earlier. RPA is the Russian Program Assurance and as described above accounts for money spent in keeping the Russian components a part of the station. Finally, VEH abbreviates vehicle design, development, testing, and evaluation.[12]

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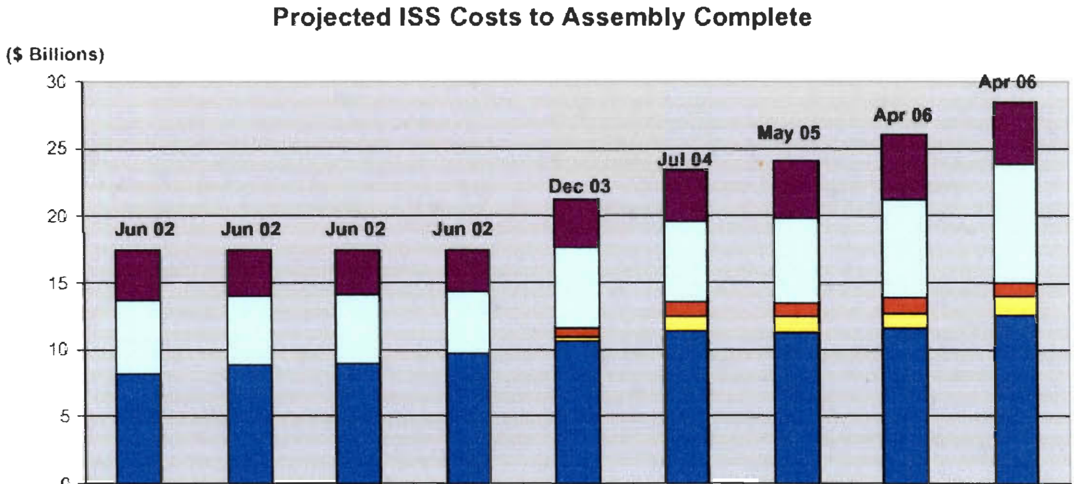
[12] IMCE Report to NASA Advisory Council, November 1, 2001.



	FY95	FY96	FY97	FY98	FY99	FY00	FY01	NOV 00	FEB 01
RES	3.7	3.3	3.3	3.1	3.7	3.8	4.2	4.7	4.7
OPS	5.5	5.1	5.1	4.5	6.1	6.0	6.4	7.4	8.7
CRV	0.0	0.0	0.0	0.0	0.6	1.0	0.9	1.2	1.2
RPA	0.0	0.0	0.0	0.0	0.3	1.2	1.3	1.2	1.3
VEH	8.2	8.9	9.1	9.7	10.7	11.4	11.2	11.6	12.7

Figure 3: Graph courtesy of IMCE Report by A. Thomas Young, et al.

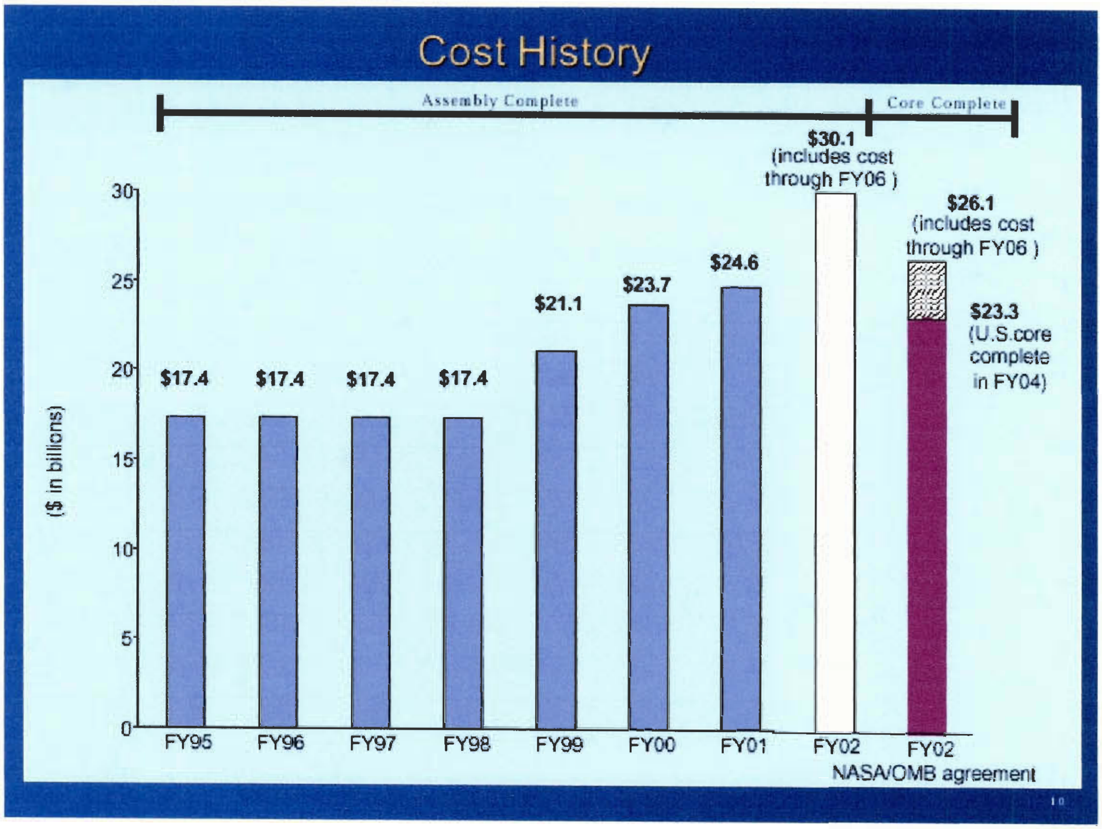


Figure 4: Chart courtesy of IMCE Report by A. Thomas Young, et al.

MINIMIZATION

Depending on the final goal of a commercialized space station, not all of the above-mentioned components will be needed. For example, a manufacturing facility would not have any use for the laboratories. By eliminating these items, the cost of creating the space station will dramatically decrease from that of the ISS. It is worthwhile to consider the possible market for space research in the development of the space station. While the facility may not be fully research motivated, a source of extra revenue could be created through one laboratory added to a manufacturing plant. Regardless, some additions may need to be added to any space factory that are not a part of the ISS. Overall, the development of these new items will be significantly less than the cost of government-developed research.

First of all, the most obvious savings are seen in the removal of the many laboratories aboard the station. Many of the modules relate specifically to research, whether exterior or interior. Nearly all of these may be eliminated immediately from the design of our factory in space, unless it is found that research is to be the product provided by the station. However, for the purposes of this analysis, it will be assumed that this is not the product. Altogether, those research components are the U.S. Lab, Centrifuge Accommodation Module, the Russian Research

Modules, the Brazilian EXPRESS Pallet, the European-added COF, and all of the JEM components. This could potentially save billions of dollars, assuming each laboratory is around $1.4 billion, as the U.S. Lab.[13]

Next, in the process of minimization is an overall reduction. The ISS is a huge undertaking. When completed, its area would cover the same amount of space as a football field. Much of that area is taken by the solar arrays; however, some significant reduction could be made. First of all, the solar arrays on the ISS will generate roughly 110 KW of power, potentially a much higher amount than needed for most commercial applications on board the station. This energy is converted to electrical energy and distributed throughout the station. Research elements require a large amount of that energy, but also, necessary life support systems account for the power absorption. By reducing the amount of energy to be used on the station, a reduction in the number of solar arrays needed could be reduced, saving millions of dollars, not only by having less solar arrays but also in the reduction of energy conversion components and less hardware necessary to ensure the attachment of the solar arrays.

Another reduction is related to the various docking locations. Scheduled for the ISS are the three Pressurized Mating Adaptors, and the Docking Module for the Soyuz. These could be reduced for the early stages of development. For the first factory in space, the initial plans need

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[13] BBC News - 02/13/2001

only one docking station, as transport back and forth would be limited. However, as the revenue grew, more docking stations could be added.

While on the topic of trips to and from the station, it is interesting to note another related fact. Each launch by the Space Shuttle to the ISS currently costs around $300 million each.[14] By reducing the number of yearly launches by three, another billion dollars could be spared each year. It is important to remember that the cost of Shuttle launches to the ISS was not included in the budget referenced in the previous chapter. The Space Shuttle has its own budget for yearly launches. Minimization of the design to meet the basic early requirements would allow for less launches. Another aspect is the use of lightweight and compact parts so that more elements could be launched per flight. An example of this can be seen in the ISS's solar arrays, which were folded on flight, by design, and unfurled once deployed on the station.

These are just a few quick money-saving ideas. For some specific information, it is important to refer to the budget released by NASA. This budget, shown in Figure 3, breaks the cost down to five categories as previously, mentioned. Of these five categories, two categories can be eliminated immediately, CRV and RPA. These two areas are involved in the guarantee of a seven-person crew. For the original purposes of creating a station for a commercial application, the crew could begin with three people as the ISS currently handles. Further, depending on the application of the commercial station, research may be eliminated. The final two categories are found in the operation of the station and the cost of components. These add up to a cost of $21.4 billion, saving $7.2 billion from the ISS budget. These final two sub-budgets is where the work must be done to reduce the cost. The elimination of a number of components and the reduction of the station to the minimum essentials for providing the safe operation will be crucial.

Later, when a number of products are specifically researched, each component will be studied for its usefulness on the commercial space station. Now, we will look at how NASA and Congress have removed the CRV and RPA components of the budget to create a "Core Complete" program. Unfortunately, some money had already been used towards these two applications before they were removed.

A final note of interest regarding the budget of an orbiting space station concerns the Russian space station, MIR. The MIR space station's total budget was a mere $4.2 billion. This total included all design, construction and operation costs. MIR orbited for a total of fifteen years (until March 22, 2001). The major difference between MIR and the ISS is clearly the size. As previously noted, the ISS will approach 460 tons while MIR was nearly 143 tons. However, the ISS being less than four times the

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[14] http://www.hq.nasa.gov/office/codea/codeae/documentc.html

size of MIR should not generate a cost that is nearly sevenfold greater. Clearly, there are some cost-effective methods that were used by Russian in developing their space station. These cost savings were spread across the various budget topics, from vehicle costs to operations. Furthermore, the Mir was quite successful in completing research, totaling 28,000 experiments during its lifetime. NASA spent $17.4 billion before a single component of the ISS was even launched. For a quarter of that cost, Russia finished the full mission of their space station.[15]

[15] http://www.cosmicimages.com/Mir/mircurrent.html

REMOVED COMPONENTS

As previously stated, Congress has been attempting to pull back the reins on the space program for a long time. The latest result of this has been the implementation of the “Core Complete” program for the ISS, developed by the International Space Station Management and Cost Evaluation Task Force. This task force was established to find cost-cutting techniques for the ISS. This section will discuss those components that have been removed in this redesign.

There are three primary elements that have been removed in the “Core Complete” version of the ISS and are rather disappointing in terms of space colonization. All of these pieces were integrated into the station in order to allow for seven-person crew occupancy. The design modifications bring the station down to a permanent three-person crew. The removed components would aid in the implementation of creating an atmosphere in space that is virtually self-sustaining. The first of these modules is the Habitation Module. This piece is required to enable the idea of prolonged space flight to become a more comfortable reality on the ISS. In brief, the Habitation Module is exactly what it sounds like, a place to live. However, this is no ordinary house for an astronaut. In past missions, the living space for astronauts has been far from perfect. For example, aboard the Space Shuttle, there is roughly 65.8 cubic meters of living space, while the Habitation Module would create roughly 340 cubic meters of living space, by design. This would seem like a mansion in space. If completed, it would contain three levels of living quarters for American astronauts living on the station. The first level would consist of a kitchen and storage area for clothing and personal items. The second level will house the mechanics for the entire module such as climate control and power, and sleeping quarters for the astronauts. The third level will serve as a bathroom and exercise area.[16]

While this may sound like wasted money, the benefits of designing such a home would be far-reaching. In order to enable true long-distance space travel and if the idea of colonizing such faraway places, as Mars and other planets were to ever be pursued such a design would have to have been tried.

Currently the travel time to Mars is around seven months.[17] In this time, astronauts or travelers would need a decent place to sleep, eat and most importantly exercise. Eventually, for the average person to consider the move to space, modern-day conveniences would be essential to their enticement. In micro-gravity, the human body undergoes a number of changes, some quite obvious and others were discovered after experimenting. However, many people from older generations will

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[16] http://www.spaceflight.nasa.gov/

[17] http://mars.jpl.nasa.gov/MPF/mpf/status/mpfstatus_050997.html

remember the astronauts from the early Apollo missions hobbling away from the Space Shuttle. Many would pass out or just collapse on the tarmac after exiting the spacecraft. In order for long-term space travel to work, space travelers would need to have an environment to use the muscles that would naturally go unused in space.

The other two components to be cut in the “Core Complete” model were the Propulsion Module and Crew Return Vehicle (CRV). The Propulsion Module is the United States’ response to the possible failure of Russia to provide the Service Module. The primary reason a substitute is needed is to provide the necessary “reboost” which maintains the ISS in its orbit, as discussed earlier. More interesting is the CRV, which is responsible for allowing for safety in space and larger crew capabilities.

The design of the CRV created a wonderful competition between design teams from various companies, besides NASA. The CRV is a unique spacecraft that is revolutionary in many ways. The main purpose was to enable astronauts on board the ISS to have a secondary means of return to Earth should any problems arise with the Space Shuttle or the Russian Soyuz rocket. This involved a number of secondary details that created an exciting new creation.

The CRV is highly beneficial to those interested in space exploration. The key element that slows the development of the colonization of space is safety. The idea of losing lives for the sake of space travel is, obviously, unpopular, to say the least. There have been a number of tragedies in the history of space travel and because of this the U.S. government tries hard to keep the average person out of space. This fear must be overcome in order for space colonization to happen.

Through the development of the CRV, space travel becomes one step closer to safety and helps alleviate those fears. Previously and currently, there are no second options for space travelers. If the astronauts currently aboard the ISS were to have difficulty with their Soyuz, they would be forced to stay there until they were able to fix the problem. (A Russian Soyuz rocket is docked at the ISS at all times). Their only second option is to wait for a new crew to replace them and swap transport vehicles, leaving the defunct one for the new crew to work on. This is a risky solution. The true risk involved was more deeply noticed recently when NASA encountered some small cracks in the fuel lines in each of their Space Shuttles. This forced the "grounding" of all Shuttles so they could be evaluated and reworked to ensure the safety of all flights. Not fully knowing the risks, NASA swayed to the safe side and fixed the problem before allowing any flights. A similar problem could potentially leave a crew of astronauts stranded on the ISS for any length of time. A CRV is an essential item in the future of space travel.

Similarly, the Propulsion Module, which was only added to the ISS's design in 1999, has been removed from the Core Complete goal.

LABORATORY FACILITIES & RESEARCH CAPABILITIES

It is important to be aware of how the ISS has been and is being used. The ISS will have a number of options for conducting research upon completion. Experiments can be conducted internally and externally, allowing for experiments to take place in a controlled micro-gravity environment or exposed to the harsh space environment. Neglecting the Russian components of the ISS leaves 37 International Standard Payload Racks (ISPR's) on the interior of the station and eight different external payload locations. The Russian components are ignored mainly because once completed the Russians will control the spaces 100% of the time in orbit.

The ISPR's are standardized racks that allow for mass-production of similar systems and simplifying the design specifications so that each experiment must fit those criteria rather than the opposite where the container would have to be redesigned for each experiment. There will be 27 ISPR's available for U.S. use and ten split between Europe and Japan. The allocation has been decided by determining the contributions from each of these countries.

The ISPR's have simplified the specifications to a simple set of requirements for each rack. The basic specifications of the racks are that they will provide 1.6 cubic meter of research space with a list of standard services provided to each researcher. The space allows for weight of up to 700 kilograms and has internal braces to allow for experiments that do not fill the ISPR.

Each ISPR will be provided with a 3-kilowatt power supply and a 1.2-kilowatt auxiliary supply with a voltage range from 114.5Vdc to 126Vdc. At fourteen locations, there will be a 6-kilowatt power supply provided. Circuit protection is also given. The temperature inside the rack can be regulated through water loops installed on the ISPR's. Temperatures can be maintained in the range of 16-24 degrees Celsius and in select locations a range of 0.6 to 10 degrees Celsius is available. Each rack is provided with the resources necessary to communicate between other racks via an Ethernet network and also to ground stations. This capability extends to video interface. All communications to Earth are facilitated by a Ku-band antenna. Vacuum lines can be utilized in 21 of the ISPR's for experiments where a vacuum is desired. Nitrogen is provided to all 37 racks while Carbon dioxide, argon and helium are allotted to a select few of the racks.

The ISPR's will be distributed throughout the ISS with the majority in the U.S. portion of the station and the remaining racks in the European and Japanese laboratories.

Besides the ISPR's, there are a number of alternative research laboratories inside the ISS. These include the Nadir Research Window, the Human Research Facility, the Gravitational Biology Facility, Biotechnology Research Facility, a Fluids and Combustion Facility, the Micro-gravity Sciences Glovebox, the Materials Science Research Facility, the Window Observational Research Facility, the X-Ray Crystallography Facility, Advanced Human Support Technology Facility, and the Low-Temperature Micro-gravity Physics Facility. Most of these are self-explanatory for their intended uses. Some quick descriptions of those that are not so obvious would be of use. The Human Research Facility is in place to study human adaptation to living in space. One study, as an example, is an experiment that is capturing radiation that passes through the ISS onto a life-sized dummy to study human radiation absorption due to the loss of protection normally provided by Earth's environment. The Gravitational Biology Facility will contain a centrifuge that allows for artificial gravity. The Micro-gravity Sciences Glovebox is a unit that allows for manipulation of the experiment by astronauts aboard the station. The Window Observational Research Facility allows for experiments for Earth observation. The X-ray Crystallography Facility will exclusively study protein crystals with components involved in their growth and those for the analysis of these crystals. The Advanced Human Support Technology Facility is in place to research technologies designed to enable human space flight to destinations deeper in space.

For external experimentation and observation, the ISS is well prepared. First, it is important to establish a coordinate system when dealing with the external payloads. This has already been done for the ISS. The six points for the coordinate system are: nadir, zenith, ram, wake, starboard and port. These directions are respectively: toward Earth, directly away from Earth, in the direction of the momentum of the ISS, in the direction directly following the ISS, to the right when facing the ram direction and to the left when facing the ram direction. The payload locations only point in four of these directions, but still allow viewing in all directions. There are eight locations that can be grouped into three sub-groups by their positions on the station. There are two mounting locations on the actual truss system of the ISS, called the EXPRESS (short for Expedite the Processing of Experiments to the Space Station). These are pointed in the zenith and nadir directions. Another grouping is attached to the end of the Columbus Orbital Facility (COF), pointing in the starboard, zenith and nadir directions. The final grouping is on the Japanese Experimental Module (JEM) which points in the port, zenith and nadir directions. The external payload racks are less standardized than the internal racks, except for those on the EXPRESS Pallet.

The external payloads will have virtually the same input parameters as the ISPR's. They will have a similar power supplies and circuit protection along with the same data transmission capabilities including ground transmissions.

The external payloads allow researchers to study all celestial bodies in view. Studies can be done on the sun, moon, Earth, stars and other planets. More detail will be given on a few of the external experiments currently in development as at this time there are no external payload mounting locations on the station[18]

The ISS quite obviously is a research facility and to that end, there have been a large number of experiments that researchers have hoped to place on the station. The process of placing an experiment on the ISS is not simple by any means. Where a researcher is interested in placing their experiment and what kind of research they will conduct determines the selection process for them. There are three Offices within NASA that are responsible for the selection of experiments to the ISS. They are the Office of Space Sciences, the Office of Earth Sciences and the Office of Space Flight. Each selection process varies across the three offices. Another issue is funding, which is also the responsibility of the individual offices. However, NASA has hoped to promote interest in the commercial market by allowing for private industry to conduct research on the ISS, at a cost. Actually, NASA has allotted a full 30% of the research capabilities on board solely for the purpose of commercial research. Currently, that price is $20.8 million for a one-year engagement on board. This price does not include a number of add-ons such as crew hours spent operating the experiment, space station energy consumption and extra weight.[19] The next section will detail some of the experiments that have been conducted on the ISS, some current ISS experiments and some that are still in development.

PAST, CURRENT AND FUTURE ISS EXPERIMENTS

One major field in which the ISS has plans for and is already involved in experimentation is in biotechnology and protein crystal growth. Major research efforts and funds have been directed in this study. The benefits are far-reaching and are best studied in the micro-gravity environment. By studying the structure of proteins scientists have been able to design higher quality and more fully developed drug. These drugs are designed by studying the structure of specific proteins and then using that information to create drugs that will increase or decrease the amount of that protein as needed.

The benefits of micro-gravity are seen in the quality of the protein structures. Gravity creates two major problems when attempting to grow crystals of any kind. These are buoyancy driven convection and

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[18] International Space Station User's Guide
[19] http://commercial.hq.nasa.gov/price/structure.html

sedimentation. Briefly, when protein crystals are grown, proteins diffuse from a solution to form orderly crystals. When this occurs the solution near the crystal has less protein and therefore becomes less dense. This causes a shift; the lower density solution moves above the higher density portions of the solution. This movement causes eddies near the growing crystal. These eddies alter how the crystal grows and creates imperfections in the crystal, making it difficult to view the atomic structure of the protein upon completion.

The second problem is sedimentation, which results from crystals falling to the bottom of the solution when the weight of the crystal overcomes the support strength of the suspension. The crystals are unable to fully develop and the partially formed crystals at the bottom begin to grow together. This ruins the usefulness of the crystals, as single crystals are needed for scientific study. Under the influence of gravity, precise measurements are impossible to achieve, thus impeding the study of the structure. Without gravity, protein crystals can be formed nearly perfectly allowing for studies that produce drugs capable of combating all kinds of diseases.

To date, hundreds of experiments growing protein crystals in space have already been completed. These experiments have flown on the Mir space station and Space Shuttle flights. These include such proteins as Gamma-Interferon, Porcine Elastase and Lectin.[20]

In the same field of biotechnology, there are further benefits achieved through space research. This is in the area of tissue and cell culturing. The process of creating tissue for use in human bodies is faulty under gravitational forces. The form of tissues generally become two-dimensional, which has little use for research, let alone transplantation. The benefits of studying human body tissues are obvious. Currently, thousands upon thousands of people are waiting on lists for organ transplantation, be it for liver, heart, kidney, etc. The current system requires waiting for a donor of similar body type to die and allow their organs to be passed on to the recipient. Many of the people on these lists die waiting. It would be a great medical achievement to be able someday to immediately begin the growth of a new organ to replace a diseased one on the same day the diagnosis is given. A lot of pain and suffering could be avoided.

In micro-gravity the medical field is one step closer to this goal. Tissues grown in space are free from the confines of gravity and are allowed to grow perfectly in their three-dimensional form. While this technology is not immediately available, the work completed on the ISS

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[20] http://crystal.nasa.gov

will further the potential for this outcome. This possibility for research will be discussed in greater detail.

Before thinking that the ISS is merely a biological research facility, it is important to consider other research topics that are ongoing. Another major field of research is in materials science. In micro-gravity chemicals can be combined in such ways that are not possible under normal Earth conditions due to their density separation. This allows for new studies to develop a wide range of materials from alloys to ceramics, polymers, glasses and semiconductors. One such material that has been developed is Aerogel. This material has a number of amazing properties, which have broken various records for strength, and absorption of heat and sound while allowing a high level of light transmission. This material will be discussed further as a possible product for the commercial space station.

Some past experiments have proven that these sorts of advances through space research are possible. Starting in the field of agriculture there have been a number of advances including studies which have increased the growth of seeds in soy beans, those that have grown plants in space and another which studied the release of ethylene in plants. The final result of the last of these experiments is Bio-Kes. Bio-Kes is a revolutionary product that absorbs ethylene. This is crucial to plant growth in space. Ethylene is the key, which tells a plant that it is time to begin the ripening process. Too much ethylene results in spoiled, over-ripened plants.[21] This is a very important subject for astronauts entering into space for months at a time as they bring all of their own food for the trip. It is a rare treat for astronauts to enjoy fresh fruits and vegetables. As astronaut Peggy Whitson said recently in a letter home, "fresh fruit and tomatoes seem like a fantasy" when she thinks back on the first few weeks of her stay on the ISS.[22] By removing ethylene from the container holding fruits and vegetables, the ripening process is slowed, thus extending the life of the plant.

This research has had direct spin-offs to commercial businesses on Earth. Thousands of dollars are lost to over-ripening fruits and vegetables in grocery stores or en route to grocery stores. KES Science and Technology, Inc. is the company responsible for the production of Bio-KES that does just what has been described above. This is a relatively small unit (36.5" x 24.5" x 3.5"), which can be installed, in the any unit carrying or holding ethylene producing plants or their products. The product works by absorbing air through its borosilicate tubes. These tubes are coated with titanium dioxide that oxidize the ethylene into carbon dioxide and water vapor. Coincidentally, this unit will also remove other dangerous gases such as volatile hydrocarbons, and airborne pathogens. This extra use for Bio-KES has resulted in yet another offshoot that can

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[21] http://www.kesmist.com/biokes1.htm
[22] http://spaceflight.nasa.gov/station/crew/exp5/lettershome11.html

be used in offices to eliminate bacteria, viruses, fungi and other airborne pathogens. Of particular interest in recent times, the unit will remove the Anthrax virus. This assemblage is called AiroCide TiO_2.[23]

An experiment that is currently vying for a position on the ISS is the "Skywatcher Instrument". This experiment is basically an X-ray instrument that is designed to capture X-rays through six X-ray cameras. These X-Rays are emitted from black holes, which possibly could be located at the center of some galaxies. This research could eventually provide further information relating to the origin of the universe. This experiment is planned for external placement on the EXPRESS Pallet.

CONCLUSION

Before getting too discouraged about NASA's decrease in the ISS components, it is uplifting to realize the benefits that do arise directly from ISS research. These encompass a number of fields of interest. The first is the obvious benefits related to studies of the human ability to live for extended periods of time. The latest Expedition crew, Expedition Four, to the ISS set a new record for continuous time spent in orbit at 195 days.[24] In doing so, scientists were able to study the effects of space over longer

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[23] http://www.kesmist.com/biokes1.htm
[24] http://spaceflight.nasa.gov/station/crew/exp4/index.html

periods of time. This is essential to the progression of establishing a society in space.

Another benefit from the ISS research is the experiments that have been conducted onboard the station. These have resulted in the development of new products for use in space and here on Earth. Also, it has been established that certain products can be manufactured either, much more easily or more perfectly in micro-gravity, giving rise to the idea of a factory in space. More than likely, once a colony is established in space, there will be a desire and potentially a need for commerce between Earth countries and colonized space countries, or states as they may be.

A final benefit from ISS research is that of an established plan for starting a community in space. A country or company in the future will be able to use the design and budget from the ISS to establish a cheaper and faster design for building a space structure intended to house a community or even just as a stopover between Earth and a space colony established on another celestial body. Obviously, the ISS has been plagued by financial difficulties. If a corporation were to design a space station, the process for doing so would be intended to produce money and become an asset. The ISS on the other hand was designed merely as a research facility. With that shift in focus, a new commercial space station would be designed much differently.

The ISS has created countless benefits to further the possibilities of space colonization, despite numerous obstacles that have been encountered over the years. The ISS has established a working research center in space that is fully functioning as so even while still under construction. The station has given scientists the ability to uncover many of the effects of long-term space travel allowing for human involved studies that probe deeper into space. Also, the station will become a docking port for refueling and replenishing supplies on a space vehicle proceeding on to these far-off destinations. In summary, despite downsizing the intended applications for the ISS, the station is a success for science and the study of space colonization.

CHAPTER 3 - COMMERCIAL POSSIBILITIES

INTRODUCTION

Space commercialization to date has been very limited. The only truly successful space industry, to date, has been in satellite communications. It would be difficult to imagine life with out satellites. They are used for transmissions of all kind, from cellular phones to Global Positioning Systems (GPS). This industry, however, has not required any human habitation of space. Branching out into the space industry with a human-inhabited product-manufacturing "factory in space" would generate a lot of press and place a high degree of risk into the hands of the first company to take the chance. Because of this, it is highly important to make sure extreme caution is taken in this pursuit and ensure that all of the proper steps are taken to minimize the level of risk involved.

The one thing a commercial space station needs to begin development is the ability for a company to see a direct line of income as a result of the investment. This section of this project will develop a few of the possibilities for a commercial endeavor. These possibilities will include not only the production possibilities but also research opportunities.

Currently, there are some product ideas such as organ tissue generation where there are direct benefits from their manufacture in micro-gravity, a quick cure for many diseases that inflict the human race, in this example. However, there is also the market for micro-gravity research. Keep in mind, the commercial price list for placing an experiment on the ISS starts at $20.8 million with additional costs for a variety of optional add-ons, such as $15,000 for one crew-hour of work by an astronaut.[25] This section will also look at some of the ways major industries could be interested by micro-gravity research.

[25] http://commercial.hq.nasa.gov/price/structure.html

AEROGEL

Introduction

Aerogel is a material that has been revolutionizing the industry of insulation. This new substance, nicknamed “Blue Smoke”, has a number of amazing properties. It has been entered into the Guinness Book of World Records for being the lightest solid known to man, also breaking its own record as it becomes more developed. The most striking quality of Aerogel is the fact that a piece just one inch thick can protect a human hand or chocolate from the heat of a blowtorch.

Another quality is that Aerogel can be made to be completely clear, so the potential for insulation as windows is incredible. If Aerogel were to be used in place of current windows, the same thickness would be the equivalent to 10-15 panes of the current material. As many know, one of the principal locations for residential and commercial heat loss is in the building’s windows. A more highly insulate material used in windows would save consumers a great deal of money, while also reducing the amount of energy that is needed to be produced, which has obvious effects passing down to air pollution.

Interestingly, it has been found that Aerogels created on Earth have a bluish hue, while space grown specimens are much clearer. Herein lies the possible market from space-manufacture. Without a doubt, humans use windows in many aspects of daily life. Cars, houses, offices, boats, and all other structures designed for human occupancy have windows installed in them. This section will start with the technical background of Aerogel development and then describe and analyze its possibilities for production in micro-gravity.[26]

HISTORY AND TECHNICAL SPECIFICATIONS

First of all, Aerogels are basically a gel-like material that has had all liquid components removed. The fundamental idea is to take a silica gel and remove all of the water and leave a highly porous "shell" which has outstanding properties. There are a number of difficulties that were initially encountered during the development of Aerogels. The primary difficulty was when the water evaporated it collapsed the structure to a much smaller size. This opposed the entire purpose of Aerogels. In order to get around this, scientists created a way to substitute the water for alcohol and which was then changed for a supercritical fluid and allowed to escape. A supercritical fluid is one that is in a state higher than its critical temperature and pressure and therefore has gas and fluid-like properties. This eliminates the surface tension associated with water that

[26] http://www.aerogel.com

was collapsing the pore structure. The result was the first Aerogel material.

Steven S. Kistler of the College of the Pacific first accomplished this process successfully in the early 1930's. He went on to market Aerogels for a few years for their use in cosmetics and toothpaste.[27] Eventually, this idea was abandoned and Aerogels were forgotten for a few decades. Aerogels have begun to make a comeback in recent decades as research has evolved and created more applications for Aerogels. Most notably, Berkeley National Laboratory and NASA have conducted research on this substance. Their interest has arisen due to its phenomenal properties.

There are a number of qualities that allow Aerogel to shine in the materials world. To date, Aerogel has surpassed all other materials for highest thermal insulation value, highest specific surface area, lowest density, lowest speed of sound, lowest refractive index, and lowest dielectric constant. Aerogel also has a high level of light transmission as previously noted for its possibilities for windows.[28]

NASA has decided to put Aerogels to use for capturing dust from a comet's tail. Basically, the dust is passing at extremely high speeds and to catch it, NASA needed to find a material that could capture it without vaporizing or distorting the properties of the dust. Aerogel is the only

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[27] http://eande.lbl.gov/ECS/aerogels/sahist.htm
[28] http://www.aerogel.com

material known that can accomplish this.[29] A summary of the technical properties of Aerogel is helpful in understanding all of its potential.

The most famous application of Aerogel is in its thermal conductivity. At 38ºC (100ºF) and nominal atmospheric pressure, Aerogel has a thermal conductivity value between nine and eleven milli-watts per meter-Kelvin. This value varies due to pressure changes. The minimum value of thermal conductivity is roughly four milli-watts per meter-Kelvin at .01 atmospheric pressure. Thermal conductivity also decreases with lower temperatures and rises linearly as temperature increases above ambient. Taking the time to compare these values to glass properties finds Aerogel to prove quite competitive. The Corning Museum of Glass, in Corning, NY, reports that the thermal conductivity of glass can be varied greatly depending on the process of its creation. However, glass typically displays thermal conductivity values between 4.23 & 10.10 (British Thermal Units times inches of thickness per hour per square foot of area per degree F). When these thermal conductivity values are converted, the range becomes 608 - 1451 milli-watts per meter-Kelvin.[30] Obviously, Aerogel has a much lower thermal conductivity and is therefore a much better insulator than any other windows.

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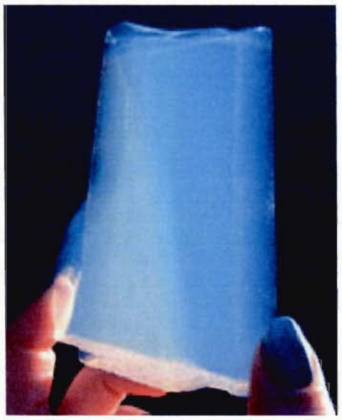
[29] http://www.space.com/news/aerogel_record_020510.html
[30] http://www.cmog.org/page.cfm?page=314

The density of Aerogel can be controlled to meet application needs. Typically, density ranges between 0.06 and 0.12 g/cm^3. Similarly, changing additives and processing conditions can vary the surface area. Aerogel is also highly flexible, conformable up to a quarter of an inch thickness. Interestingly, Aerogels that have not been wrapped in another material will float on pure water indefinitely. Further on this topic, Aerogel can be covered by a variety of materials to further enhance specific qualities. As mentioned previously, Aerogel readily absorbs sound waves. To quantify this property, the speed of sound in Aerogel is roughly 100 m/s.[31]

[31] http://www.aerogel.com



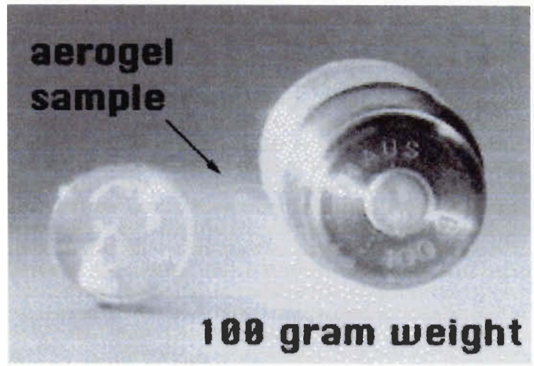


Figure 5: Aerogel created on Earth. (Courtesy of http://www.tonyboon.co.uk/aerogel/aerogel.htm)

Figure 6: Clear Aerogel in front of a penny. (Courtesy of NASA)

Apparently, Aerogel is a revolutionary product in the realm of material science. The applications span a number of markets and its physical properties are astounding. Now the question of how this product can be used to further the progression of humankind into space colonization. In order to accomplish this step, Aerogel must be marketable and reliable in production. This section will address these issues.

As discussed earlier, the primary Aerogel product that benefits from space-manufacture is in the field of highly insulate windows. Research in this area is limited, although it is apparent that Aerogels definitely see benefits when produced in space. STS-95 (Space Transportation Systems, Flight #95) was a Space Shuttle Discovery flight sent to study the effects on pore-size of Aerogel created in micro-gravity. When Aerogels made in Earth's gravity are compared to those made in micro-gravity there is an obvious benefit in pore-size. Basically, the pore size is what determines the degree of light transmission through the substance. The larger the pores, the more refraction occurs and the less clear the image becomes. The smaller the pores, the more light can pass through unaffected. This principle is the same as that makes the sky blue; the shorter wavelengths pass through while longer ones are refracted. This is why Aerogels often have a bluish tint in color when created on Earth. This is highly important to the application of windows. No matter how much money could be saved in energy costs, people do not want to look out through a blue window.

Transparency, therefore, is highly important in this application. Space manufactured Aerogels pores are around 50% smaller and are much more acceptable for use in homes and offices. Unfortunately, at this time, the process has not yet been perfected and it is not cost-effective.

Currently, there are very few companies commercially producing Aerogels on Earth. The main producer is Aspen Systems who have developed a way to manufacture blankets, thin sheets, beads, and molded parts made from Aerogels in a timely and cost-effective manner.

CONCLUSION

Unfortunately, it seems that Aerogel is not currently viable as an option for space production. There are already other materials that will accomplish the intended applications for Aerogel at a fraction of the cost. The main benefit to space-manufacture would be in the field of insulating windows. The energy savings created through producing Aerogel windows are not significantly higher than the extra cost associated with growing Aerogel in space. Considering each launch alone costs $300 million, the cost per sheet would be fairly large. The launch cost can be assumed to be the primary cost to overcome in this product, since the machinery, which may be expensive, is only an initial payout. After that the costs associated with running and maintaining the machinery and the support systems should be minimal compared with the launch costs. Also, there are some issues associated with this venture, as there is a great deal of vibration on the descent into atmospheric reentry. This might be found to be damaging to large panes of Aerogel windows.

ORGAN TISSUE GENERATION

INTRODUCTION

Another viable option for space production or research is in the field of tissue and cell growth. As mentioned earlier, there is an enormous need for organ transplants in America and the rest of the world. In the Scientific Registry of Transplant Recipients' 2001 Annual Report, a number of statistics concerning the need for organs in the United States is delivered. The University Renal Research and Education Association, a group of investigators, staff and colleagues from the University of Michigan compiled this data. For the purposes of this project, these data will be used to show the great need for organs. After the need is established, current developments in the area of tissue growth will be discussed, followed by the benefits of tissue growth in space.

ORGAN TRANSPLANTATION IN THE UNITED STATES

As required by the U.S. Organ Procurement and Transplantation Network, the following statement must first be made prior to the use of the data.

> The data and analyses reported in the 2001 Annual Report of the U.S. Organ Procurement and Transplantation Network and the Scientific Registry of Transplant Recipients have been supplied by UNOS and URREA under contract with HHS. The authors alone are responsible for reporting and interpreting of these data.

As previously stated, the following statistics have been taken from the Scientific Registry of Transplant Recipients' 2001 Annual Report. The numbers of people affected by organ transplantation in the United States is a staggering number. This next section will outline in a quantitative method how large this affect is. The statistics released deal with the time period from 1991 until the year 2000. For the purpose of saving time, only the first and last of these years will be detailed.

First of all, it is essential to know that the following organs can currently be transplanted: the kidney, heart, liver, lung, pancreas and intestine. The total number of Americans waiting for any kind of organ at the end of the year 2000 was 89,361. In 1991, this number was considerably less at 37,658. A large number of people died during these years while waiting for an organ. In 2000, 4920 died while in 1991 there were 2416 deaths while waiting on an organ list. The number of donated organs from the deceased in these years was 21,578 in 2000 and 15,609 in 1991. From this point, it is helpful to look at each organ individually to see individual necessities.

We find that the kidney is the most sought-after organ with 47,831 people waiting for a transplant at the end of the year 2000. In 1991, this same number was a mere 19,046. There were a total of 10,795 kidneys donated in 2000 and 6,662 in 1991. 2,806 people died while waiting in 2000 compared with 1,012 that died in 1991. The survival rate for kidney recipients after five years was established to 81% for those receiving kidneys from deceased donors and 91% for recipients of living donors.

The next dominant organ is the liver with 16,874 people waiting in 2000 and only 1,527 in 1991. There were 5,372 livers donated in 2000 and 3,187 in 1991. 1,661 people died while waiting for livers in 2000 and 515 in 1991. The survival rates after five years for liver recipients is a mere 75% for those received from dead donors and 81% from living donors.

4,124 Americans in 2000 and 2,162 in 1991 wanted the heart. There were 2,286 donated in 2000, 2,198 in 1991. 592 died in 2000 while waiting for a heart and 790 in 1991. The survival rate after five years for heart recipients is 70%.

The lung had a waiting list of 3,666 people in 2000 and 683 in 1991. 850 lungs were donated in 2000 and 399 in 1991. 480 people died while waiting for lungs in 2000 and 137 in 1991. The survival rate for lung transplants is only 43%.[32] The next few pages summarize the above data into graph forms to facilitate quick access to values.

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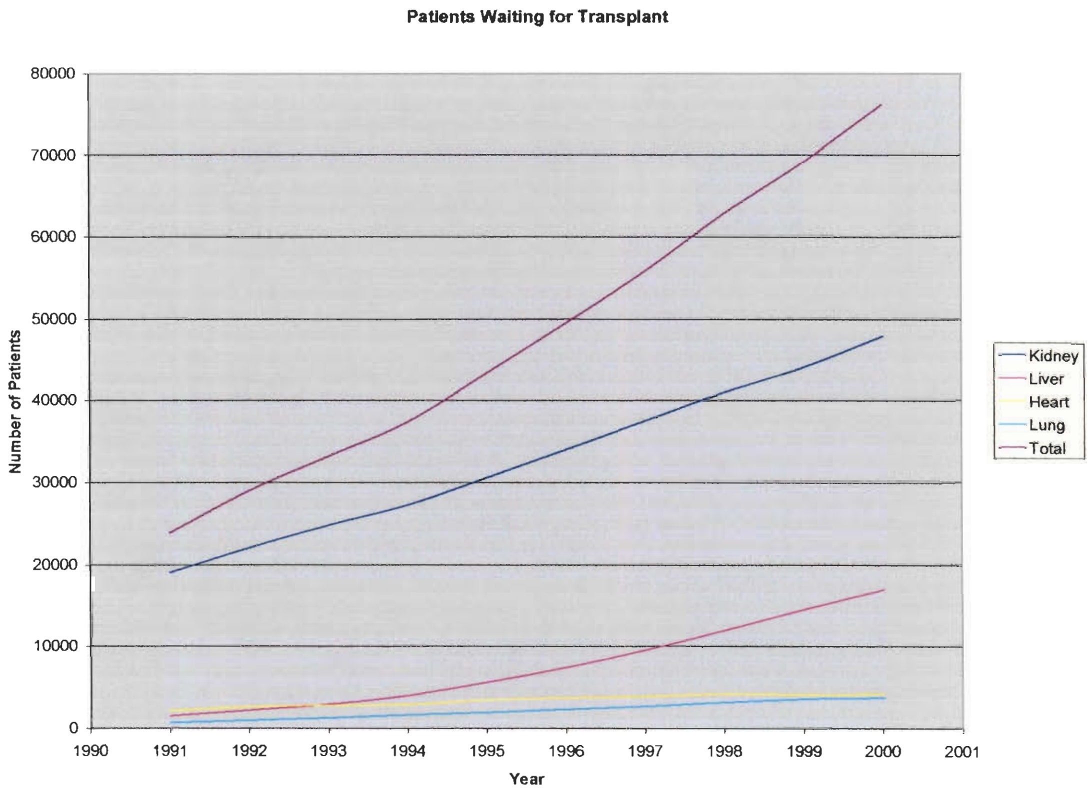
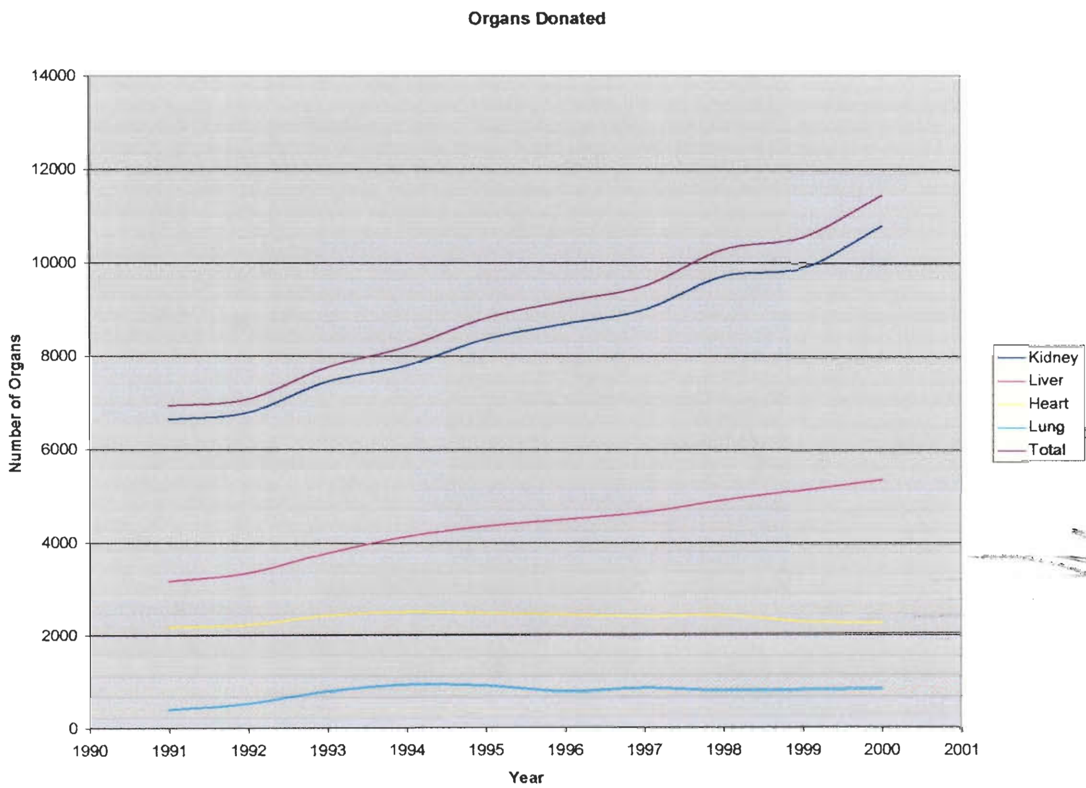
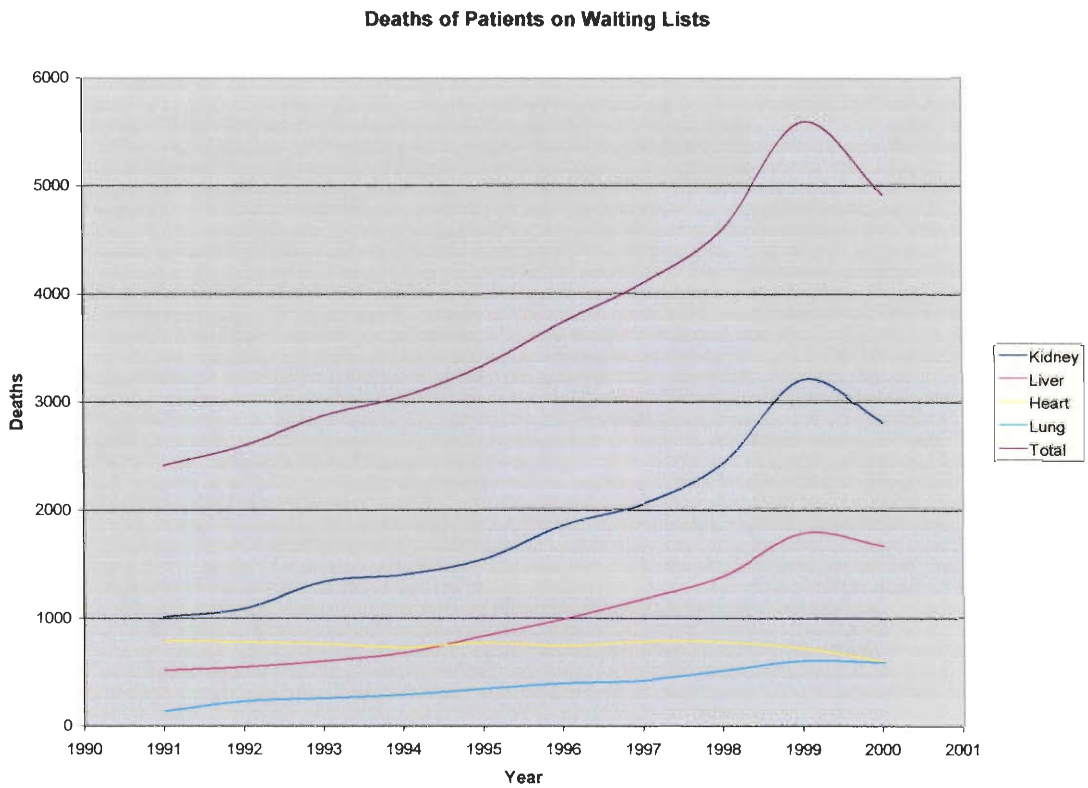
[32] 2001 OPTN/SRTR Annual Report



Patients Waiting for Transplant
80000
70000
60000
50000
40000
30000
20000
10000
0
Number of Patients
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year
Kidney
Liver
Heart
Lung
Total



Organs Donated
14000
12000
10000
8000
6000
4000
2000
0
Number of Organs
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
Year
Kidney
Liver
Heart
Lung
Total



Currently, a patient's financial status and societal status have little to no effect on whether or not they receive an organ. From one patient's experience, the father of this paper's author, Phillip Gordon, the process goes as follows. There is one list containing all of the people in the United States waiting for a liver. This list is broken down into sub-lists, based on life expectancy. The highest level is reserved for patients with less than twenty-four hours left to live. The lowest level patients are in the earliest stages of organ degradation. As a patient's condition worsens, they advance through the various classifications. Upon reaching the top level, they become the top priority for receiving organs that become available. This does not necessarily mean that they are guaranteed to receive their much-needed organ. A number of factors come into play. A donor must become available in such a situation that the blood-type matches, it can be delivered to the patient in a short period of time and no other patient is higher on the list for receiving that organ. Once receiving the organ, the patient undergoes a lengthy process where doctors attempt to uncover the exact balance of drugs so that the body does not reject the new tissue, which is viewed as foreign and thus is attacked.

From these numbers, it is quite obvious that there is a significant population in America that is dying from or has died from the need for an organ. With thousands dying every year, there has been a great deal of research into new possible options for organ transplantation. Some current studies involve using organs from other large animals such as pigs, growing organs in a laboratory and injecting molecules that are designed to induce the regeneration of damaged or missing tissues inside the person awaiting a transplant. One important piece of information is the fact that skin tissue growth has already been fairly well established in a laboratory setting. One of the main problems with complex tissue growth is the fact that on Earth gravity makes the results of such experimentation two-dimensional as opposed to the obvious three-dimensional needs.

SPACE POSSIBILITIES

In micro-gravity, there are a number of possibilities for tissue and organ growth. The first step would quite obviously be experimentation. There is a great deal of experimentation still required before organ factories can even begin development. One option for an initial space station is a biomedical facility in orbit with a number of scientists working towards the eventual goal of organ growth. On Earth some studies are taking place concerning how fetuses grow and cell growth in smaller species. The results from these studies could be taken to micro-gravity in order to research artificial growth in micro-gravity. As science progressed, eventually, methods would be developed capable of producing functioning three-dimensional organs replacing parts for ailing humans all over Earth. At that point a full-scale factory could be placed into orbit, built off of the earlier laboratories or started anew, transforming the laboratories to the studies of other areas.

Obviously, the price on such an item would be quite large, facilitating the costs of research. Fortunately, there is already a high cost associated with transplanting organs. The process of extracting the organ from either a living or deceased donor is added on to the cost of inserting the organ into the recipient. For example, the liver transplant that Phillip received in 1997 was tremendously expensive: $280,000. Besides the fact that organs are already expensive, the frequency of deaths that occur as a direct result of ill individuals not receiving an organ drives the demand and resulting price tag up. Since, the current system does not take into consideration a patient's financial status, some patient's might be lower on the list and more willing to pay the higher cost to receive a new organ.

Besides the potential for patients to receive treatment earlier through the availability of organs, eventually, organs could be produced that would reduce the recovery time and the effective hospital costs. This would be done by reducing the drug experimentation while searching for the necessary intake to avoid rejection by the body. The ideal solution to this problem would be to take a piece of the patient's organ and send it to the factory in space so that the new tissue could be built from the existing healthy tissue. Patients waiting for an organ transplant are already subjected to a steady requirement of biopsies for analyzing the remaining tissue in the organ. This would almost positively ensure there would be no rejection of the organ by the body, as the tissue would be familiar. Transplants could be safer with a much higher survival rate than has been experienced in the past.

In order to accomplish this end result, organ tissue would have to be launched in mass quantities, grown and returned to Earth for patient use. With early detection, as is already common, this process would occur much more quickly than the current system where patients generally wait years before receiving a transplant or dying from not receiving one.

BUDGET

For a true analysis, a rough budget to the greatest degree of accuracy must be developed. Based on earlier numbers relating to the ISS, a launch to the ISS has a price tag of $300 million.[33] Assuming the sample tissue needed to grow the new organ to be small, a large number of patients could be served through one flight. Using the dimensions of the Space Shuttle's payload bay, here are some ideas. The Shuttle is capable of housing roughly 42,000 cubic feet and 63,500 pounds.[34] An unmanned shuttle specifically designed to transport organs could eventually be developed, but for the purposes of this analysis, the Space Shuttle dimensions will be used. Assuming an organ is returned in a container of ten cubic feet and roughly ten pounds, the limiting factor would be the space available. If the organs and their containers were stacked to the maximum capacity, each flight would be capable of transporting 4,200 organs. This is of course a rough estimate used for the basis of hypothesis. Given the price of $300 million per flight, the base price of flight costs per organ becomes just around $70,000. Now, there are a number of extra budgetary guidelines to keep in mind.

One reason that the cost per organ is not actually too expensive is that the cost of $300 million per launch is based on the average cost for a launch to the

[33] http://www.hq.nasa.gov/office/codea/codeae/documentc.html

ISS. These launches contain ISS equipment such as laboratories and other heavy structures. On Earth, organs are transplanted in coolers filled with ice after being inserted with a preserving chemical. In space transportation, the entire payload could be a cooler with small individual containers for each organ, thus enabling the organs to be packed closer together and reducing the necessary weight from refrigeration equipment. Undoubtedly, this total weight would be less than that for a payload to the ISS carrying heavy structural equipment. For example the U.S. Laboratory alone weighs roughly 16 tons. Also, when leaving Earth, the weight of the payload would be even less than when returned as the payload would mostly be small tissue samples rather than full-sized organs. Much of the costs associated with Shuttle launches are due to the high costs of fuels in the solid rocket boosters and the Space Shuttles Main Engines. With the reduced weight for the entire duration of the flight, the volume of fuel could be greatly reduced, this would in turn lower the weight again allowing for even less fuel as much of the weight is also due to the large amount of fuel on board. The savings in fuel would be translated into great cost reductions, thus again minimizing the cost per organ per flight.

Another factor to keep in mind when analyzing the cost involved in creating organs in space is the savings that the patient would receive in other areas. By organ growth in space, the organ would be grown from the patient's own tissue,

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[34] http://www.spaceflight.nasa.gov/shuttle/reference/index.html

thus reducing or even eliminating the chance for rejection. This process is costly, due to the high volume of prescription drugs being consumed and the hospital costs related to recovery. The recovery rate would be increased, as the body would more easily accept the new organ. These savings may ease the burden inherent in the cost of space-grown tissues. Another more obscure financial consideration is the fact that, theoretically, the patient would be able to return to work earlier due to the reduced recovery time. Furthermore, the survival rate would more than likely increase as the main reason for death in an organ recipient is due to rejection of the new organ. The costs associated with an early death are quite obvious both financially and personally. The longer a person is alive, the more they are able to contribute to society, as if the benefits of extended life can be quantified. However, it is apparent that when these extra factors are considered, the cost of $70,000 per person becomes a much less substantial figure.

CONCLUSION

The possibilities for organ tissue growth are valid. There is a well-established market for organs created artificially. The benefits would reach past the financial gains to the venturing company. The public as a whole would benefit from the increased safety and decreased response time in transplantation. There are some difficulties that must first be overcome before the idea becomes a reality.

First of all, there is still a great deal of research to be done to actually enable the process of growing fully functional organs. This is process is in no way close to understanding at this time, but the potential exists. Another difficulty comes in the high costs associated with the endeavor. Possibly in the time it takes to develop the process, the costs might come down. Primarily, the launch costs must decrease. Other costs are also important, though being omitted for brevity. These include the costs relating to the FDA and other government restrictions placed on the field of medicine. For something as serious as the growth of artificial organs, there will be strict laws and costs associated with such a process. However, someday there does exist the possibility of a space-based organ factory, saving lives many thousands of times over.

A BRIEF LOOK AT OTHER OPTIONS

A few other important options for potential investors to consider are the possibilities surrounding ideas that have been omitted from this project for the conservation of space. The possibilities that have been briefly mentioned are crystal growth, in any form or a research platform, created for lease to companies and scientists. However, it is important to realize that the possibilities surrounding space commercialization are endless. This project could not be considered complete without at least the mention of a few other commercially viable options.

One option that has received a great deal of publicity and energy in recent years is that of space tourism. Undoubtedly, there is a great deal of potential in this pursuit. To date there has been two space tourists, Dennis Tito, followed by Mark Shuttleworth, reportedly paying $20 million each. A lot of attention was brought about by the possibility of singer Lance Bass becoming the third space tourist with financial backing by TV producers planning to film the event and develop a TV series based on the premise of reality TV in space. Plans were halted due to the inability to come to an agreement with the Russian Space Agency. However, the potential market in this area is quite enormous. The creation of an orbiting hotel in space has been tossed around as a future endeavor. Many companies have been created in the pursuit of this development. A few changes must be made before these options become a reality.

The previous two paying visitors to space have been added as additions to flights scheduled for experimentation, taking the seats of astronauts. However, if a space hotel were created, the tourists would need to be shuttled in an inexpensive fashion. Unfortunately, the current rate of $20 million per person does not cover the $300 million per launch that was previously discussed. At that rate, each flight would require fifteen passengers just to cover the flight costs, let alone other obstacles such construction of the hotel. In order for this idea to truly develop there must be some dramatic economic changes in flight options.

Another topic briefly mentioned is the possibilities of crystal growth in space. As previously mentioned, crystals in space can be created with a much higher level of clarity. There is a large market for crystals of many forms. Some possibilities are their use as protein crystals and laser crystals. As previously mentioned, protein crystals grown in space have great potential for the creation of drugs to fight diseases. Laser crystals on the other hand have a great deal of use in military applications.

Lasers are highly energetic beams of a particular wavelength. The defense industry is interested in high-powered lasers for their ability to destroy a variety of targets in a short period of time. The most interesting characteristic in the field of defense is their capacity to "shoot" at the speed of light, creating instantaneous results. This also allows for a high volume of shots within a short period of time. These high-powered lasers are being studied in their abilities to combat Intercontinental Ballistic Missiles. Laser crystals are needed to generate the great deal of energy necessary for the destruction of these missiles.

CONCLUSIONS

At this time, it seems that most possibilities for space commercialization are not cost-effective. As stated in the introduction, for a company to risk an investment into such a venture, there must be strong evidence of potential gains. In the current market of capitalism, risk assessment is an enormous industry, given a great deal of importance. Companies and people in general are in favor of minimizing risks. Currently, the commercialization of space through the creation of a fully commercial space station does not minimize this risk.

However, this is not to say that a commercial space station will never exist. Trends show that the costs associated with space transportation is decreasing as technology increases. Space transportation costs seem to be the greatest cost to overcome in regard to space manufacture. The costs of the actual manufacture of any product are similar whether in space or on Earth; building costs are expensive regardless of the setting. Therefore, the costs of the transportation are the most important hurdle to decrease.

According to researchers at NASA's Marshall Space Flight Center, there is work being done to reduce these transportation costs. The division of Advanced

Space Transportation has set a goal to achieve a cost of only $100 per pound by 2025. This would be quite an accomplishment as the current price for shipping to space is roughly $10,000 per pound.[35] By realizing the potential for costs to decrease through the next decades, it is important to speculate as to when the above ventures could come to fruition.

Now, taking the example of organ growth in space and analyzing the decrease in space transportation costs, the following becomes evident. The cost for organ growth in space was found to be $70,000 per organ, just from the transportation costs. With the one hundredth decrease in transportation costs, the price per organ becomes a mere $700! This is an outstanding price for the saving of a life. The decrease in transportation costs would far outweigh any building or operations costs associated with the venture. At this price, it would be unbelievable if the process was not completed and utilized. The question becomes at what price will the risk associated with the manufacture of organs in space be reduced to a point where companies would eagerly begin construction.

If the price for space transportation was reduced to 10%, the price becomes $7000 per organ. This is still very little considering the costs of $280,000 for current organ transplants. It seems that if costs were cut in half, companies would undoubtedly gain an interest in the process of space manufacture. At this rate, the per organ cost would be a mere $35,000 for transportation costs. This

[35] http://www1.msfc.nasa.gov/NEWSROOM/background/facts/astp.html

is a mere 12.5% of the total current cost of an organ transplant, seemingly a small enough percentage to pursue the idea. So, it is proposed that if space transportation costs were reduced from $10,000 per pound to $5,000 per pound, space commercialization would at the very least begin serious speculation. By the time, the cost drops to $1000 per pound, space manufacture would become nearly commonplace. These numbers might not be too far off if the Office of Advanced Space Transportation achieves their goal of $100 per pound by 2025.

CHAPTER 4 - IMPACT OF SPACE STATION ON HUMANITY

INTRODUCTION

There are a number of factors that are less evident when the discussion of space colonization arises. Generally, people think of a select list of topics, such as where to go and how to get there. Specific to the topic of space manufacturing, the topic of what product to research and develop in space tops the list. However, there are a number of topics that are more social in nature, as opposed to practical. These questions require discussion on the way people live on Earth and how this way of life would be affected by the installation of a space station.

For space colonization to develop there would have to be a community of people living in a relatively small area. They would be required to live, work and sleep together. The crews on the International Space Station (ISS) and those on MIR in the past have had to deal with these situations. As the idea of space colonization is discussed further, a look at the effects of such an arrangement will be presented with notes taken from groups who already have spent or are spending an extended time period in space. Further thought will focus more on further space colonization with the establishment of larger colonies, either in orbiters, planets or another celestial body.

SOCIAL EFFECTS

The social effects of living in space are enormous and NASA and other space agencies have spent a lot of time trying to gather and analyze data concerning the well being of astronauts. As the idea of space colonization develops, some questions arise. The overall question is how will living in micro-gravity affect humans' way of life? This question can be broken down into a variety of simpler questions.

Some of these questions will be more important than others, but the answers will only truly be realized through experimentation and research. However, it is of great use to attempt to study these questions analytically so as to develop topics for further research. This project will focus on a short list of questions and look into whether or not they have been tackled in any way. Regardless, some hypotheses on the effects of how micro-gravity will affect various aspects of life will be presented.

First of all, the most important question is in regard to procreation. Many physical phenomena occur only with the aid of gravity. While there have been a number of studies conducted dealing with human ability to survive in micro-gravity, the ability to continue life has had limited development. There is one scientist who has conducted a small amount of research on this topic. Joseph Tash, a principal investigator from NASA, has studied the mobility of sperm in space. He used sea urchin sperm for this investigation and found that in micro-gravity the sperm were more mobile although the effects of this increase are unclear. As a follow-up to the space research, Tash and his associates performed the same experiments under hyper-gravity, increasing gravity to 5g's. This, he found lowered the ability of the sperm to navigate quickly. It is apparent therefore that gravity does have an effect at the most basic level of reproduction.[36]

Apart from these studies, little to no research has been conducted. However, this discovery leads to a number of other questions. Most importantly, if the sperm are more mobile does this mean that fertilization will be improved? The effects are not entirely clear. It does seem that improvement in the functionality of the sperm would mean increased production, but this is not entirely true. The timing of the fertilization may be quite important and if the sperm were to reach the egg too soon, other problems might arise. (Tash's experiments involved only the sperm due to the difficulty of capturing and transporting an egg without changing the natural processes of fertilization). The only way to truly find the answer is through complete experimentation, breeding in space.

Further, what if it does mean fertilization is more easily facilitated in space? Does this mean space will become overpopulated more quickly than Earth, thus destroying the early colonies and the endeavor of space colonization? Or, will

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[36] http://spaceresearch.nasa.gov/common/docs/highlights/Gravity_Shown_to_2001.pdf

this result in research into a higher quality contraceptive? The answers to these questions are unclear and only time will reveal them.

Proceeding from this point brings the question of children. How would the process of raising children vary? Imagine an already rambunctious child tearing around a confined area in space. The initial space habitats would a bit on the small side for raising children. How would children dispense their immense sinks of energy? A parent would be unable to tell their children to go play outside, as there would be no outside. Maybe as technology advances, the ease of extravehicular activities would be increased to a point where some form of sporting events could take place outdoors. Sport enthusiasts would need to design a jet pack to be used for playing sports, or some other way of propelling a player to their destination. More than likely, a new series of sports would evolve that makes use of the micro-gravity role or large stadiums with simulated gravity could be built eventually. Would the Space division of baseball compete against Earth teams? That would bring new meaning to the term “home field advantage”.

Another factor involving children is their muscle and bone growth. It seems at first look that the lack of gravity would have a detrimental affect. Astronauts easily understand the necessity to exercise while in space, using treadmills and the like to build muscles and fight their deterioration due to lack of use. It would be much more difficult to convince a child to run on a treadmill as a way of life. As usual, their exercise would be found in the games they play, so games would need to be developed to work their basic muscles. It is questionable as to whether or not humans will even continue to value muscle growth. If a truly independent colony were ever established, there would never be gravity for its residents. It is easy to imagine that these residents might someday ignore their muscles and allow them to degrade. This is especially possible when the current state of Americans health is considered. Americans have a growing trend of obesity as fast food becomes more prevalent in the society and machines do more of the strenuous tasks of day-to-day life.

At first it may be thought that teaching children could pose to be difficult in micro-gravity. For example, how do you teach someone what gravity is without them having experienced themselves? It seems that it would be much easier for an Earthling to imagine life without gravity than a spaceling to imagine life with gravity. It may be thought that some topics would be more difficult than others. Children today ask an unending list of questions about their surroundings. Children in space would have to be taught these things. A parent would need to describe trees, oceans, animals, seasons, snow, and all other natural phenomena. While at first this may seem more troubling, in actuality, children on Earth are already taught innumerable things that they are unable to experience directly. For example, children in South Dakota cannot directly experience the waves of an ocean easily, yet, they still understand basically what an ocean is. It seems that with practice, gravity and Earthly objects could also be explained to a child.

Another topic of discussion is what the influence on Earth will be by space residents returning to Earth. It seems that people who have been to space might have a higher awareness of their insignificance. Having seen Earth from a distance allows space travelers to better understand how small and fragile this world really is. However, the affect to humankind as a whole would be unsubstantial. Even in the distant future there is little chance that a large space colony will be established. It is more likely to continue as it has with small groups in space. With only three astronauts on the ISS at a time, their return to Earth is not enough to change society as a whole. The space population will have to grow substantially to begin to affect the Earth population. By that time, it is more likely that the mood in space will have changed to reflect more strongly the Earthly mood rather than the current mood of awe that commonly occurs in space.

Questions concerning an adult's way of life, rather than a child's would be more prevalent. A child's brain is much more plastic and open to belief of unseen ideas and objects. If a true establishment were to ever be created, all aspects of human civilization would more than likely follow. People, no matter where they live, have a few basic needs and desires that would need to be fulfilled. Some examples of these include hospitals, schools, restaurants, movie theaters and bars. The next section will study how some of these areas have been dealt with already and ideas for future development.

TEACHINGS FROM THE PAST

The Space Shuttle was only designed to orbit for roughly two and a half weeks. This allows for little time to observe living in the environment with micro-gravitational effects. The establishment of the ISS and its predecessors has allowed for a great deal of studies concerning extended life in space. This tool has impacted the idea of space colonization in amazing ways through this research. Previously, the effects of long-term space flight had been theorized but studied very little. Crews aboard the ISS now stay in orbit for a few months at a time.

Recent studies have ranged from highly scientific to just the every day descriptions of life in space. Peggy Whitson, an astronaut from the Expedition Five crew, which docked in June of 2002, has maintained a correspondence back to Earth. In these letters home, she has described not only the experiments and work she completes but also the day-to-day life aboard the ISS. These letters are quite interesting and show a great deal of insight into living in micro-gravity.

Through the process of maintaining a permanent establishment in space a few key life-sustaining areas have begun development. The topics include eating, drinking, hygiene and breathing. All of these every day activities become more difficult when orbiting 240 miles above the Earth's surface.

This next section will describe the current ways of dealing with these issues and possibilities for the future. The first topic will be food and drink. This was one of the very first fields of interest when space flight was originally considered. The main question was whether or not the human digestive system would work without the aid of gravity to move the process along. With the first early endeavors into orbit, this question was answered. Famous astronaut, John Glenn, was the first person to consume food in space. This was during the very first Mercury missions. At that time, NASA's primary method of dealing with food was to freeze-dry it, converting into a powder for consumption. Another means of eating was to create a powder, which could be mixed with water in space to create a food that was in between a liquid and a solid.

This has been revolutionized a great deal. In those early missions, a major problem was the creation of crumbs that could potentially ruin the sensitive equipment on board the flights, thus endangering the astronauts' lives. Now, the major problem facing astronauts is which meals to choose and the problem that taste changes in space. A number of space travelers have reported disliking foods that are favorites on Earth. These days, astronauts are given a list of possible foods prior to flight and their meals are planned months in advance. They even have a nutrition specialist review their dietary plans so as to ensure their necessary supply of nutrients. There are a number of choices for astronauts on the ISS and those involved in Space Shuttle missions. There are five basic categories for space-consumed foods and from these astronauts create a diet more variable than most humans on Earth experience. The five categories of food are rehydratable foods, thermostabilized foods, intermediate moisture foods, natural form foods and irradiated meats.

The first of these, rehydratable foods, is basically the same as the early Mercury missions although much more controlled with more variety. The basic process for eating rehydratable foods is to mix the packaged food with a certain amount of water and wait for the food to absorb the water. This process is highly controlled; each packaged food is labeled with the appropriate water dosage and wait time. On the ISS, water is added in a strict manner. A needle is poked into the package and the dosage and temperature are selected from a machine, which pumps the water through the needle into the package. Some foods that astronauts eat in this manner are scrambled eggs, shrimp cocktail and macaroni and cheese.

The next process is thermostabilized foods that are processed on Earth to eradicate possible viruses and other contaminants. These foods are heated in an oven, if necessary, and cut open with scissors to be consumed. This is similar to TV dinners on Earth. Possible thermostabilized foods include grilled chicken, tomatoes and puddings.

Intermediate moisture foods are those, which are not fully dehydrated prior to packaging but have limited amounts of water in them to decrease the microbial growth. These foods include dried fruits and dried beef.

Natural form foods are those which can be eaten immediately and require no extra preparation. Some examples of these are snacks such as crackers and chips.

Irradiated meats are meat products, which are cooked, packaged and irradiated through exposure to radiation prior to consumption. This ensures that the meat provided to astronauts is healthy and edible.

While this food may seem unappetizing and stale sounding, it is common for astronauts to spice up the food with a variety of toppings. Salt and pepper are provided in packets mixed with oil (pepper) and water (salt). The reason for the liquid mixture is to decrease the chances for contamination of ISS hardware.

The topic of drinks in space is another area of difficulty. In the absence of gravity, liquids float in drops of varying size. Pouring drinks is no longer possible as the liquid floats out of its container propelled by whatever force was last exerted upon it. Obviously, opening a can of Coke in space is quite different than on Earth. The carbon dioxide knows no buoyancy in space and is therefore randomly distributed throughout the liquid; this creates a "frothy mess" and is in no way as satisfying.

Due to the possible contamination of equipment, beverages are highly controlled also. Liquids are stored in a pouch that can be drunk through a straw. Even the straws in space are different, though. They must have a little valve, which stops the fluid from escaping when the straw is not in use.

There are a few options for beverages in space. Most flavors are developed in the same way as Tang and other instant drinks. A powder is mixed with water, stirred (or shaken in this case) and consumed. Many beverages can be made in this manner, such as iced tea, apple cider and hot chocolate.

However, if the development of space were to truly increase to the population of even a small town, there would eventually be a market for a different sort of beverage. One of the biggest industries in the world today is in alcohol. When this market is expanded to space, there are a number of difficulties and great possibilities that will be discussed later.[37]

It is apparent, however, that despite all of the progress that has been made in the diets of astronauts, there is always room for improvement. Food on space is by no means comparable to that on Earth, although some space food products have been marketed to a degree of success on Earth.

In a development from the alcohol industry, there has already been research into the consumption and production of beer in space. One student of Colorado State University, Kirsten Sterrett, decided to complete her master's thesis on the study of beer fermentation in space. Her experiment with the aid of a few companies, including the Coors Brewing Company, eventually flew aboard a space mission. The end result was a beer similar to those produced on Earth.

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[37] http://lsda.jsc.nasa.gov

In a related study, Coca-Cola sent an experiment into space aboard the ISS to study the dispensing of the fluid. The goal was to enable astronauts to have a drinkable form of their product. The machine was equipped with a computer to regulate the temperature and minimize agitation of the fluid. The beverage was dispensed into a sack, which was inside of a pressurized bottle so that the fluid was squeezed out of its container at a controlled rate.[38]

In the future, it will be essential to the morale of space residents to create a more expanded array of choices when visiting the local bar or restaurant. Food will need to be more appetizing although the presentation could be enhanced through micro-gravity. Chefs would have to revolutionize the idea of food placement. A serving on a plate would not be possible, as the food would merely float away.

Bartenders would also have to change their methods. No longer would bottles be available to mix drinks in a glass. One possibility would be the invention of a machine capable of being a mini-bar. Instead of a bar rack with the bottles displayed behind the bartender, there would be a computerized machine with a library of drinks. The machine could be programmed to take the selected drink option and mix the appropriate doses of each element to be dispensed into a drinking container. There would have to be a huge room devoted to the possible liquids so that upon a client entering his or her choice,

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[38] http://science.nasa.gov/headlines/y2001/ast21sep_1.htm

the machine would dispense the liquids to a pressurized mixing container to be dispensed to the client. The technology behind the money exchange has already been developed in cash and credit operated machines which are seen everywhere. There could still be bartenders who would take the money, punch in the selection and pass out the drinks. Undoubtedly, there would have to be some supervision of the drink dispensing as there is on Earth. Bartenders still serve a purpose by keeping activities safe and controlled. The machine could even be programmed to "shut people off". By an ID system, the computer could find out the weight, sex and history of the person to determine their drinking limits. This would have some legal complications but eventually could be enforced. The technology developed in this field could be passed down to Earthly bars and restaurants.

HYGIENE

Hygiene in space is much different than on Earth. The entire concept is obviously different. On Earth there are a few things we take for granted. The first is obviously gravity, but the second less obvious is the ever-present supply of water. Neither of these is quite so readily available on a space station, although eventually, the goal for space is to have a system that completely recycles everything so that nothing goes to waste. In fact, the goal is to create an Earth in space.

The first difficulty, however, is the lack of gravity. On Earth gravity plays a major role in cleanliness. To shower, we stand under a stream of water that flows mostly due to the pressure and partly due to the aid of gravity. Gravity is a major aid in the drainage of this water. Without gravity, machines such as suction and exhaust fans must be used.

On Earth, water is used for all aspects of hygiene, from showering to brushing of teeth to shaving and urinating. In space, these processes must be changed to accommodate micro-gravity and to conserve water.

Currently in space, showers are taken in an entirely different fashion. Basically, astronauts clean by taking a sponge bath. A rinseless body bath solution is applied to a washcloth and massaged throughout the body. There is no need for rinsing so little water is used or wasted. For shampooing, a rinseless shampoo is used. This process was originally developed for hospital patients who are unable to exit their beds to shower. Most astronauts choose to shave using an electric razor to save the hassles of shaving with limited water. Everything that would usually be done with a stream of water on Earth is done using a washcloth or towel in space.

The toilet is a topic of discussion that has undergone major changes in its introduction to space. Plumbing is entirely different. Fans to a waste container suck wastes down.

Interestingly, water is very essential to life and how it is dealt with in space is quite useful for the study of urban planning. In cities, water must be conserved at times in order to allow a water supply to be maintained. Earth is essentially its own recycling center in this aspect. Water is rained down on Earth, which is used by humans and animals alike. The processed water is expelled in a variety of wastes; sweat, urine and water vapor in breath. These wastes are then eventually evaporated back to the clouds during which the wastes are cleaned out and in the absence of air pollution returned through rain as pure water.

In a space station situation, this process is not easily replicated. However, there is much research currently in development so that eventually all water will be continuously recycled. Water vapor in the air and urine from humans and even laboratory animals along with water used for other purposes such as cleaning will be recycled back to a unit which purifies the water and returns it for use. On a side note, another source of water is found in the Space Shuttle's main engines, which burn hydrogen and oxygen forming water as one of its by-products.

Similarly, air is a much-needed component of life. The production of breathable air is a complicated operation in a place where there is little to no atmosphere. On board the ISS, air is primarily created through the electrolysis of water. An electrical current is transmitted through water breaking the bonds to create oxygen and hydrogen in their gas forms. Currently, the hydrogen gas is discharged into space as waste, but eventually scientists hope to recycle this to. The hydrogen could be combined with carbon dioxide to produce water and methane, thus enabling the reproduction of water while the methane would be emitted from the station. On Earth, plant life and other biological systems do this task for us. An idea for the future of space is in the growth of gardens, which would benefit residents in a number of ways. First, the plants would absorb the carbon dioxide in the air that is exhaled by humans and at the same time expel breathable oxygen; they would also serve as a source of food for future astronauts. Reliance on this sort of system is a long way from conception, however, due to the deadly possibility for failure. Plants die, but machines can be fixed if errors are encountered. Also, plants require much more time and energy be spent on their upbringing. Therefore, currently, astronauts and NASA prefers the use of machines to recreate the atmosphere experienced on Earth. Someday in the future, plants could be created with more reliability in space and could possibly be used as the primary system with machines as a back up for emergency situations. This will take further growth of the space population before it would be enacted, though, as plants also require more living space.[39]

[39] http://lsda.jsc.nasa.gov

BUSINESS ECONOMICS

Moving away from the everyday social effects of space colonization brings up the topic of economics. This is a broad topic encompassing such sub-topics as importation, exportation, and investing. However, this report will attempt to focus on the changes between the daily lives of space residents as compared to their Earthly counterparts. Also, a brief section will consider the effects that could be felt in the world's financial world.

Earthly money is nearly undisputedly at the top of the average working person's mind. Everywhere someone looks there are the effects of this. Advertisements commonly share an infinite number of ways to "get rich quick". Undoubtedly, finances are very important in this world, even so far as being the number one reason couples fight. Dealing with this issue in space, could simplify daily lives or possibly complicate it. With a bit of advanced preparation, the issue could be averted to a minor shift in current methods.

The first problem with the current system is the actual existence of money. Money is more of an idea; the actual physical aspects of money are not required for the idea to live on. Recent financial trends have led to fewer physical exchanges of money. With the increase in credit cards, debit cards, on-line banking and the like, money becomes more of just an idea and less of a physical object. In space, this is absolutely imperative. As discussed previously, launches are obviously quite expensive, currently. It would be ridiculous for a space-bound colony to continue to tote large bundles of money in the physical sense up into orbit. The first established colony in space will have to resort to a fully computerized system for dealing with money. Incomes will have to be directly deposited into bank accounts (paper in any sense, checks, bills, etc are not lightweight). Once deposited credit cards and debit cards will be the primary access to the money. Banks in space would be fairly fictitious in nature. There would be no actual building at first. Potentially, with the advancement of space, a sort of customer service center could be established although this seems highly unnecessary. Most people have credit cards which they have never had physical contact with a single person responsible for the effective operation of the card. Customer service contacts can be established online and by phone.

On Earth, there are very few businesses left that do not accept major credit cards. In space, there would be none. Money, in the physical sense, would lose all value in space as the opposite would occur, where cash is no longer accepted and businesses are run on a electronic system only. As businesses eventually migrate to space to provide new residents with the amenities of Earth, the current problems that occur in electronic exchanges would have to be fully worked out so as to minimize the chances for failure. Without cash as a backup, it would be necessary to ensure that the electronic systems work without fail. A simple computer crash could put a company out of business at least, temporarily.

Another business related issue is the absence of workers in space. Primarily, the inhabitants of a space-based colony would consist of the original workers for the factory or research laboratories. As this facility increases in size, there would be a market for other businesses to send up facilities for the workers. Primarily, the first support businesses would probably be restaurants, movie theaters or other forms of entertainment. These support businesses would have a lack of lower-wage workers in space for obvious reasons. For restaurants and the like to function on Earth, there is an obvious need for workers. For example, restaurants need wait staff, cooks, and bartenders. In the early beginnings, businesses would likely start small. Restaurants would have one primary worker, similar to a local, small-town restaurant where the owner does most of the work. The initial entrepreneur into this field would need to be a manager, chef, waiter, host and bartender. Luckily, the demand would be low at first, but as the colony grows through the presence of more space-based business, there would need to be a solution to the problem of workers.

Undoubtedly, it would take the power and innovation of a large restaurant chain to branch into space products. One possibility for the addition of workers would be to sponsor contests on Earth where the winner is offered a free trip to space, free room and board, so long as they work in the restaurant. Assuming a large restaurant corporation were to make the advance to space, they could hold the contest among their current workers. More than likely, low-wage earning workers would be eager for a free trip to space. A small salary could be paid to ensure the covering of debts maintained on Earth. The candidate would need to be well suited for the position as the release of an space employee presents problems of its own. If an employee quits or is fired, would they be required to pay for their flight home? There would have to be some way to get them back to Earth, there would be little room at first to deal with the unemployed work force.

This scenario could be applied to other markets; a movie theater chain could send a highly advanced movie theater into space. It would be the first large-screen viewing opportunity in space. There would, however, need to be a revised method for viewing movies for a number of reasons. Reels of film would add excessive weight and costs to a movie theater's launch into space. Also, with the weekly releases of movies, there would need to be variety in space. One possibility would be to create a new sort of digital movie theater. A company on Earth could send the latest releases to an orbiting space station through a secured data transmission once a week. These movies could be downloaded on to the station's movie computer, which would be able to transmit the images on to a large screen for customer viewing.

POLITICAL EFFECTS

Politically, there are a few laws that will need to be established and/or revised to accommodate space colonization. Current government restrictions do not allow private companies to launch humans into space. These restrictions would need to be bypassed prior to any venture that puts men and women into space for commercial reasons. Also, there are a number of legal questions that arise when considering the governing bodies in orbit. Currently, there are astronauts from a variety of countries on board the ISS. Which country governs these space residents? Currently, it seems that each sector of the ISS is governed by whichever country claims ownership for that sector. This issue has not yet even arisen, as there have been no instances of "space crime". It's hard to imagine a highly paid astronaut finding a reason to commit vandalism, for example. As a space colony grows, these issues would need to be considered.

Starting with the changing of laws, it is necessary to consider what laws govern the commercial space industry, as it exists today. The Federal Aviation Administration (FAA) is responsible for this law enforcement. One department of the FAA in particular has been delegated this task. This office is the Associate Administrator for Commercial Space Transportation.

For the proposed markets described in the previous chapters, all situations require the presence of workers. It is essential to at least consider the possibilities related to sending essentially, factory workers into orbit. The same process that takes place for sending a payload, such as a satellite, into orbit could be translated to include human payloads. When a commercial payload is launched into space, the launching company must first submit a report to the FAA, which details the exact specifications of the launch. These specifications include the launch facility, booster rockets to be used and safety details. The topic of safety is the main point of interest for human space flight. The parameters regarding launch facility and rocket could be the same, but safety requirements would have to be amended. Current safety requirements are the submittal of a proposal that shows the what measures are being taken to ensure the safety of the surrounding area. Worst-case scenarios involving explosions must be considered and a risk assessment must be provided to the inspection officers. The launch must be planned to reduce the risk to surrounding areas near the event. The FAA receives the documents, reviews them for validity and then field-inspects the launch area to determine the level of safety. Once this is completed, the launch will be allowed to continue, postponed, or canceled. To advance this process to include human space flight, companies would need to submit documentation to ensure the safety of the passengers. A set of guidelines would need to be established that would aid in this process. The current process is more pointed to safety in the case of an explosion, while with passengers on board; the explosion would need to be avoided. In order to qualify this, inspections similar to those that take place at NASA prior to a launch would have to be made into law. Various parts inside the rocket and orbiter would need to be inspected thoroughly. It must be shown that the rocket and orbiter will not fail in such areas of fuel leaks and air leaks. The orbiter's propulsion system would have to be tested to be reliable under space conditions to ensure that the passengers can be returned to Earth in the event of an emergency.

CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS

This paper was written to present a few ideas relating to the topic of space colonization. It was established in the beginning that the progression of space colonization would have to start through the creation of a self-sustaining, permanent space station. From that establishment, the International Space Station (ISS) was described in detail to show a guide for beginning this endeavor. The ISS is a worthy guide as it has become nearly self-sustaining, with crews commonly staying in orbit for up to six months. However, they are visited frequently with fresh supplies. Eventually, the goal of the ISS is to become self-sustaining, but this will not happen within the near future. The author of this paper feels that for true space colonies to be established, there will eventually be a need for commercialized space station.

The commercial space station would have many differences from the ISS, depending on its eventual application. First, a few ideas for minimization of the ISS were presented. A chapter that dealt with the possibilities for a commercial space station followed this. A few specific topics were chosen, Aerogels and Organ Generation. Hypothetically, both of these products could be eventually produced in space, along with the other products briefly mentioned. However, not all are feasible in the present age.

Organ generation alone shows the greatest promise for a space-based, human-controlled company. There is a great need for organs all over the world, with many people dying daily for failure to receive an organ or for organ failure after receiving a donated organ. The seriousness of the product along with the high demand results in a viable space-bound product. Humans are willing to spend a great deal on their health. This is easily seen by going to a drug store and looking at the cost of pharmaceuticals. Organ transplants currently run for a few hundred thousand dollars. Space-grown organs would many benefits to the customer, mainly, the early availability and the lowered chance for organ rejection by the body. That alone would save thousands of dollars to the customer in ways such as reduced hospital stays and reduced drug intake. This author feels that currently, the best option for a space company is to first research the process of growing tissues in space and eventually, begin production.

After discussing the possible options for a commercial space station, the final chapter regarding the eventual effect on humanity that would result from the establishment of a space colony was detailed. This is an area that little thought has been taken. Governmental space agencies have considered such topics as survival in space and the psychological effects of space living but not the overall trickle-down effects to society. While this topic is extremely abstract, this report tried to present a few ideas relating to this in social, economical and political aspects of life.

This project should be used as a quick guide to space colonization, but is by no means complete. There are many areas of life that need to more fully developed for space before a space colony is created. Also, a company interested in space-manufacture would need to look quite a bit deeper into the possibilities prior to venturing into space. This is a serious endeavor and should not be entered into lightly. There are many risks involved in space travel and these factors should be considered along with the possible markets for space products. This project merely presents some ideas with relatively quick analyses. However, it is hoped that this discussion is useful for those who intend to further investigate the many possibilities of the commercialization and colonization of space.

GLOSSARY

CAM - Centrifuge Accommodation Module
CRV - Crew Return Vehicle
COF - Columbus Orbital Facility
EVA - Extra-Vehicular Activity
EXPRESS - Expedite the Processing of Experiments to the Space Station
FAA - Federal Aviation Administration
ISPR - International Standard Payload Racks
ISS - International Space Station
JEM - Japanese Experimental Module
LEO - Low Earth Orbit
MPLM - Multi-Purpose Logistics module
NASA - National Aeronautics and Space Administration
OPS - Cost of Operation of the ISS
PMA - Pressurized Mating Adaptor
RES - Research Costs on the ISS
RPA - Russian Program Assurance
SSRMS - Space Station Remote Manipulator System
VEH - Cost of Vehicle Design, Development, Testing & Evaluation

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