Chapter 1 - Introduction

This IQP will examine the possibility, viability and commercialization of man-tended platform. Since man has been in space, there has always been battle of whether space exploration or activities should be performed by manned or unmanned concepts. Each has its implications that for each scientist might seem practical. In light of the recent accidents to the space shuttle, NASA has taken a lot of heat as to the possibility of performing its activities using robots. It seems with the advancement of technology, the use of unmanned space exploration is becoming more practical. The man-tended platform concept would be finding the middle ground of the man or unmanned argument and performing far better than that of its predecessors.

Some of the factors that result from the manned and unmanned debate are based on money and safety. In regards to safety, unmanned seems to be the most practical vehicle to use. In the worst case scenario, machines worth millions of dollars are lost and not human lives. This was clearly evident as the world watched astronauts burn to death in the accident of the space shuttle Columbia. If the exploration was performed by robots, it would have eased the heat NASA had to take for the spacecrafts malfunction. In regards to money, unmanned exploration is also the best vehicle. Robotic exploration is less expensive because care is not placed into the safety of the robots. The environment in the spacecraft doesn't have to be habitable for human life which is very costly to create. Manned advocates claim that manned exploration is effective. The bottom-line of every mission to achieve a certain goal regardless of the money and safety aspects. If the mission fails, all the money used to fund it goes to waste. Hence, spending the necessary money and gambling on the safety of human lives is necessary to achieve a mission.

The concept of man-tended would be used to answer the debates regarding the money and safety of manned and unmanned space activities. In man-tended, a platform is created which has the possibility of housing crew in a mission. The bulk of the platform would be used to perform spacecraft activities using unmanned instruments such as robots. If the need arises for a human to perform a complex activity, then a crew member could be launched to the platform to fulfill the duty. In terms of money, it would be cost effective because it would be using a combination of manned and unmanned attributes. It would be expensive than unmanned but the efficiency of the man-tended would overrule the money factor. In terms of safety, the housing on the platform could prove to be a safe haven for the crew in case of shuttle malfunction. Since the platform will have the capability of repairing minor problems that would occur in a mission, safety can be nullified with the man-tended platform.

To better propose the efficiency and effectiveness of a man-tended platform, the IQP examines three companies that would highly benefit from this concept. These three case studies would be performed on satellite televisions, global positioning systems and satellite radio. By looking at these three companies, we can access their space activities and correlate it to the activities of the man-tended platform. Some of these activities will include looking at the design, launch and maintenance of satellites. Since satellites are the primary vehicle used by today's industry to achieve their goals of advanced communications, basing our research on satellites seems to be the best avenue to explore man tended.

In order for the man-tended concept to be accepted, the public need to recognize the market need of the vehicle. This market need would be highlighted in the case study.

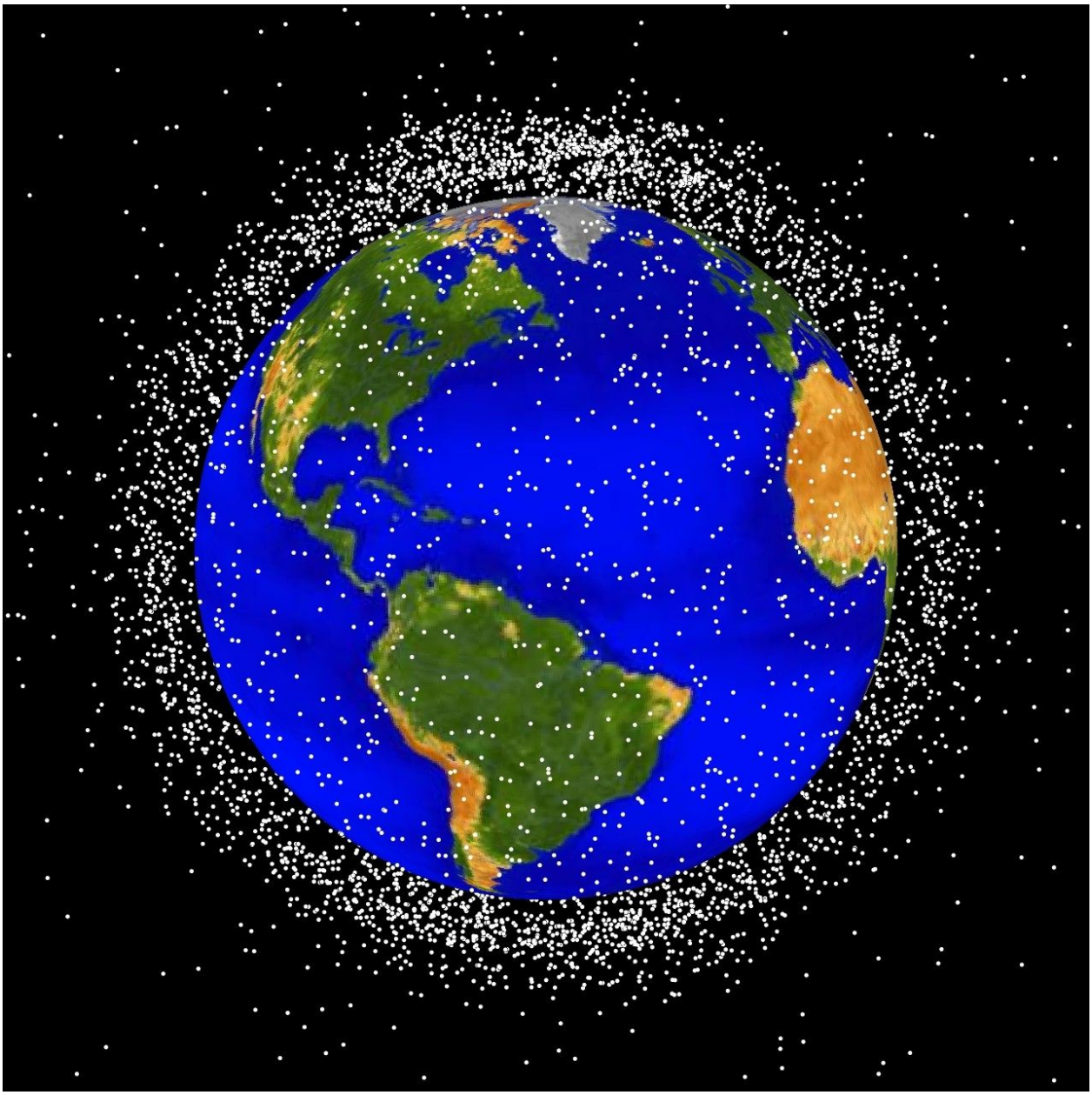
By looking at the problems and difficulties that lie in the space industry, the IQP will attempt to solve them and create a market need. To embellish this market need, the man-tended concept will also introduce new ideas that cannot be performed by either manned or unmanned. To conclude the project, we will create a model to analyze whether our concept was able to fully solve all the projected problems of the case study. The model would include a rating system that will score the effectiveness of each solution. This score would be compared to the solution if manned or unmanned concepts were used.

Chapter 2 - Literature Review

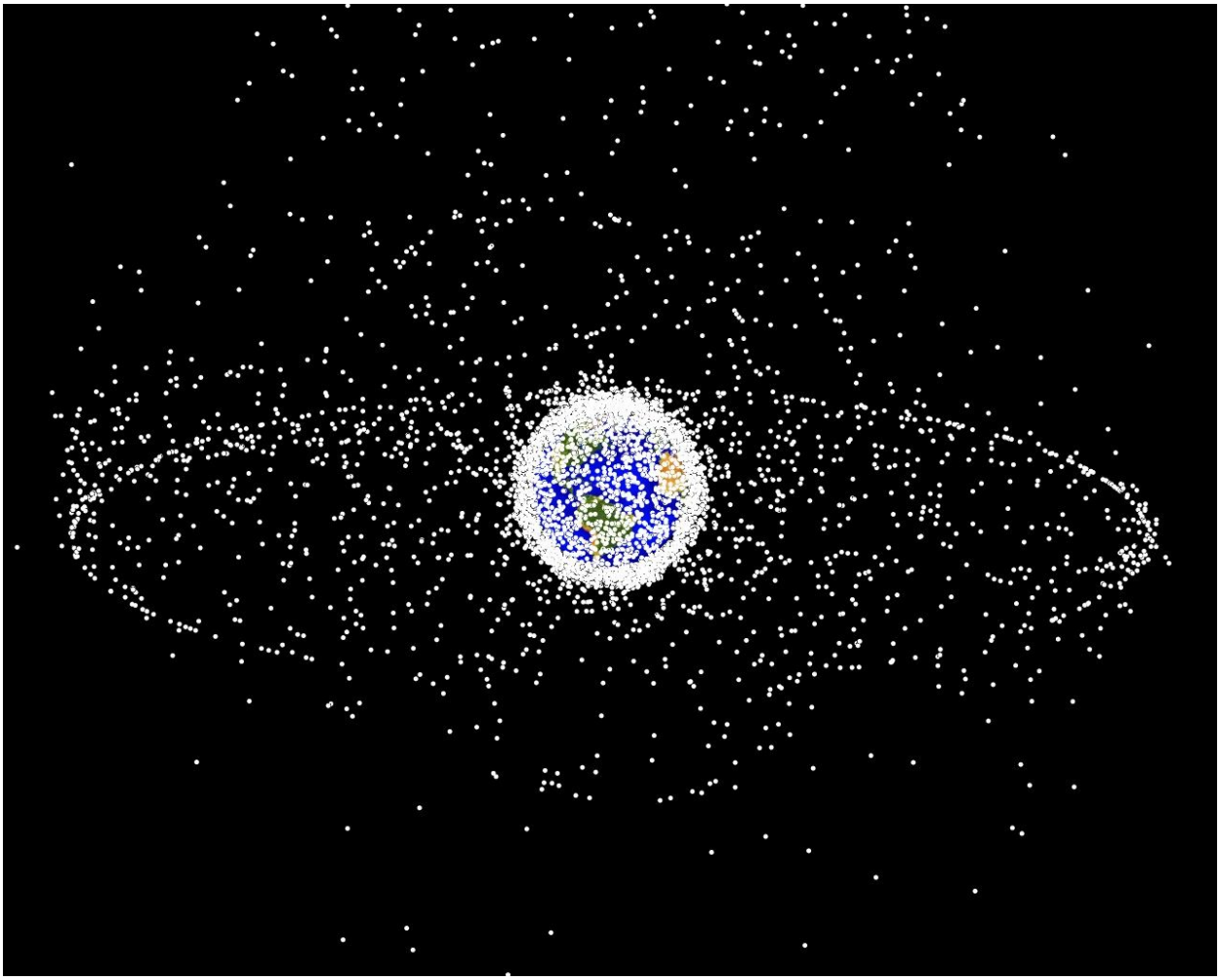
The Man-Tended Concept

Currently, each company launches their own equipment into orbit. 811 active satellites are currently tracked in orbit.[1] The sky has essentially been divided up into positions where a company can place equipment. When the equipment fails, it floats around as garbage and that satellite position is lost. Repairs generally are not done at all; new equipment is launched to replace the old. The result has been a steady increase in the amount of debris that orbits the Earth. An estimated 4 million pounds of space garbage orbits the earth; the debris field around Earth is comprised of about 110,000 objects larger than 1 centimeter, and as of June 21, 2000 there were 8,927 man-made objects being tracked by NASA, with 2,671 of these being whole satellites in either working or non-working condition. Such garbage poses a potential hazard to astronauts, as even a speck of paint off one such satellite once pitted a space shuttle window.[2] The following pictures illustrate the debris field created by such waste.[3]

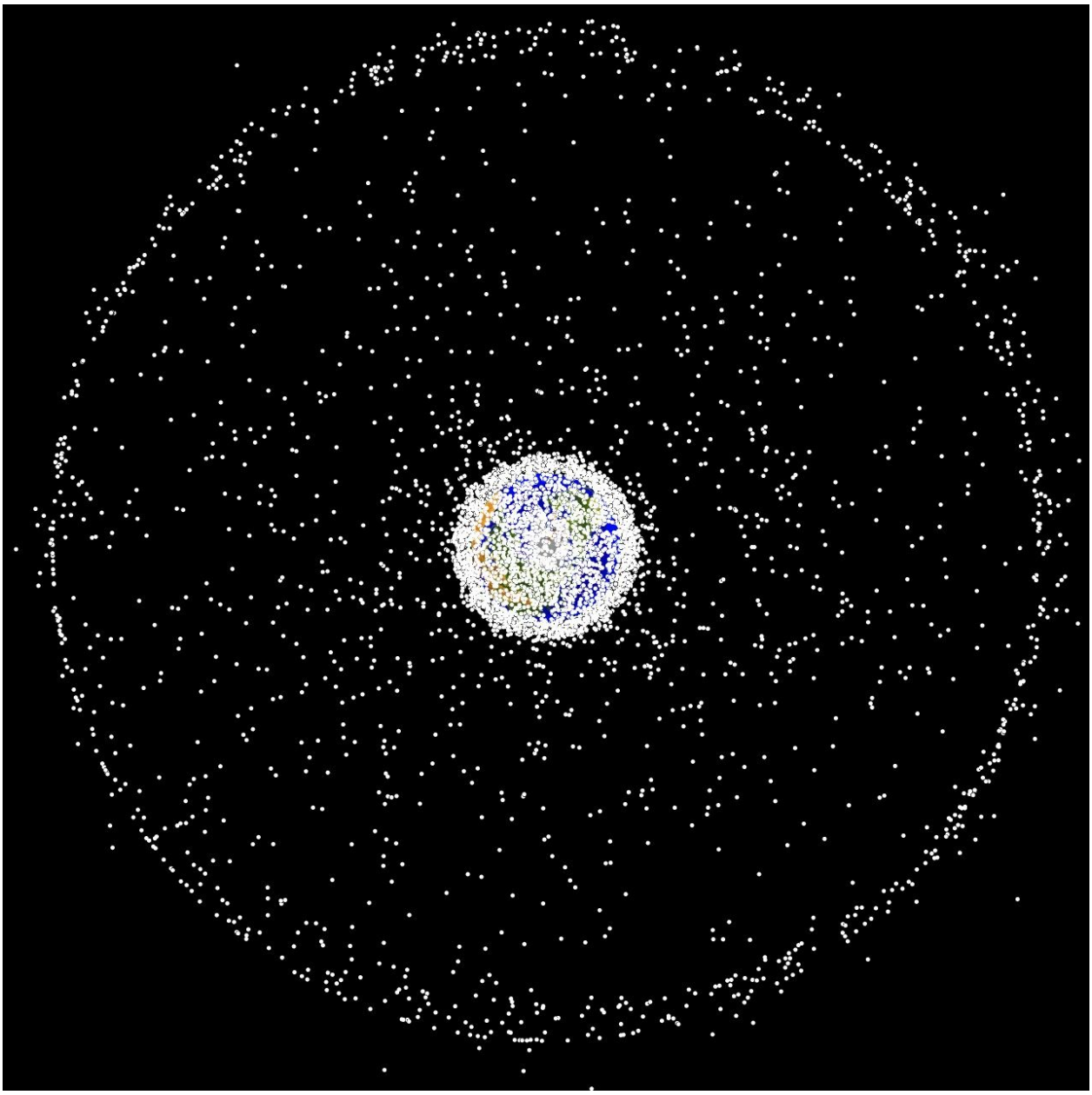
[1] http://www.ucsusa.org/assets/documents/global_security/UCSSatelliteDatabase_11-15-05.xls
[2] http://www.space.com/spacewatch/space_junk.html
[3] http://www.orbitaldebris.jsc.nasa.gov/photogallery/beehives.html



Earth’s Low Earth Orbit Debris Field



Earth’s Geostationary and Low Earth Orbit Debris Field



Earth's Geostationary and Low Earth Orbit Debris Field, Polar View

While studies are underway to reduce the debris field's size, it is necessary to reduce the amount of waste released into orbit in order to avoid having the problem grow larger. One potential solution is the use of man-tended platforms. Such a platform could be called a super satellite, an orbiting platform that could handle multiple pieces of equipment. Companies that need to have equipment in orbit could contract with the holder of such a platform, and multiple

functions could be consolidated into one unit. Under such a contract the platform would provide common support systems for all equipment installed. Furthermore, this "super satellite" could be given a maintenance schedule. It could be designed and placed into such an orbit that a team could go up on a regular basis to perform repairs and upgrades. Under their contract the platform holder would handle installations, repairs, and upgrades of all equipment provided by the companies using the platform.

Using man-tended platforms would have several advantages over normal satellites. Due to being able to maintain equipment and clustering it, orbital space would be conserved and space garbage would be reduced. Companies could potentially save money by not having to invest in support systems and by being able to repair and upgrade their equipment. Multiple pieces of equipment could be sent up on the same launch, allowing the different companies involved in one platform to split the high cost of launch.

http://www.cnn.com/2003/TECH/space/02/18/sprj.colu.space.future/index.html

NEED
Information on allocation of space to satellites

Hubble Space Telescope and Columbus MTFF

In our study of man-tended platforms the Hubble Telescope is an important example to study. It is the closest thing in existence to a man-tended platform at the moment. Hubble is an object put into space and does its job unmanned, and has been intercepted by a manned crew for maintenance. The difference between this and a man-tended platform is that Hubble does not have a regular maintenance schedule, it just gets worked on when it needs it.

Hubble lets us study a current case where an object in orbit is maintained and what is involved with doing such a task. In addition the Hubble case gives us a more important aspect to

study: the means used to perform that maintenance. How much of the work should be done by machine before man takes over? With the recent trouble with the space shuttle, NASA has cancelled all shuttle missions except for those going to the International Space Station. Outrage in the scientific community followed this decision since it meant the cancellation of mission SM4, the installation of the Wide Field Camera 3 and the Cosmic Origins Spectrograph (both instruments are already constructed and waiting to be installed) to Hubble as well as the replacing of its batteries and gyroscopes. Without the upgrade, Hubble will fail as early as 2007.

The result of the outrage was the concept of a robotic mission to repair Hubble. A robotic arm would be sent up with the replacement equipment, attach to the back of Hubble, and perform the necessary servicing. The problem with this plan was that we lack the technology to do this, so the technology has to be developed before the mission can proceed. Development of the robotic arm began and at the same time an independent study of the robotic mission was performed by The Aerospace Corp. The robotic arm project was halted when the study determined that the project cost would be around two billion dollars. It's important to note that the average manned mission cost is five hundred million dollars, which means it would be significantly less expensive to send men to perform the maintenance. This has caused NASA to re-evaluate what the last mission to Hubble will accomplish; at the very least it has to be intercepted and dropped into the ocean. NASA is currently taking into consideration various robotic missions and at the same time not ruling out sending men to Hubble, but wish to use a robot to do most of the SM-4 mission tasks in late 2007 to early 2008.

In short, the Hubble Telescope case gives us an important example to study. It is currently the closest example we have to a man-tended platform. At the same it helps in determining whether or not robotic maintenance to equipment is a viable and cost-effective

option or whether it is best to use a manned maintenance crew instead. A repair mission to Hubble in June 2000 cost $205 million, of which $110 million was for a shuttle launch and crew. Current technology will not allow for a cost effective robotic maintenance of a platform, as development costs at this time are too high. If robotic maintenance is to be viable the technology must be developed; the viability of manned maintenance shall be evaluated later in this paper.

http://www.space.com/news/050429_hubble_griffin.html
http://www.space.com/news/ft_hubble_cost_041207.html
http://www.space.com/missionlaunches/hubble_response_040714.html
http://www.thespacereview.com/article/257/1
http://www.edcheung.com/job/hrsdm/hrsdm.htm
http://www.space.com/news/hubble_cost_991206.html

An equally important case study to consider is the Columbus Man-Tended Free Flyer. In 1982 ESA conceptualized the "Columbus" program, which consisted of an attached laboratory module that could be attached to the at the time proposed US Space Station complex or utilizing the Eureca platform and a Resource Module would be able to function on its own as a man-tended free-flyer. The original intent was to be able to make the laboratory switch between the two options. Studying this is important to the goals of our project because all elements (the launcher, shuttle, and orbiting module) were designed for regular visits by man to change experimental setups and perform maintenance.

ESA began work on the Columbus Attached Pressurized Module in 1985. ESA continued on the concept of a module that would be attached to a space station but also detachable for the purpose of performing microgravity experiments. Due to a deadlock with the United States over whether this capability should be allowed, it was decided a year later to build a separate Man-Tended Free-Flyer module. In November 1987 approval was given to start work on the MTFF along with the Hermès shuttle and the Ariane-5 rocket (the service vehicle and its

launcher). The cost for the entire project (APM, MTFF, and an unmanned polar remote sensing platform) was estimated at $3.56 billion.

The Hermès was designed to be a 6 person transport, but this design was reduced to 3 after the Challenger disaster prompted ESA to design a crew ejection system. Another redesign, this one to make Hermès lighter, was to add a disposable "Resource Module" to the back of the shuttle. This module stored cargo and let Hermès dock, and was jettisoned before the shuttle returned to Earth. In 1991 the program was reduced after the total program cost was figured at $7.663 billion and $4.576 billion additional for the Ariane-5. Finally, in 1992 everything was cancelled except for the APM, which was repurposed as a module for the International Space Station.

Although the Man-Tended portion of the Columbus project was cancelled, it is still very important in the study of man-tended platforms. Before its cancellation, ESA had basic designs for all the components necessary to have a platform that would autonomously orbit and perform experiments with periodic visits from man to maintain equipment and change experiments. The most valuable lesson to be taken from the Columbus project is that with current technology and design techniques the largest hurdle that a man-tended platform faces is budget.

http://www.abo.fi/~mlindroo/Station/Slides/sld073.htm
http://en.wikipedia.org/wiki/Hermes_(shuttle)

Market Growth of Satellite Communications

From the first launch of the soviets Sputnik satellite, there has been competition among nations and companies launching different satellites for communications. With so much money involved in the cost and launching of the satellites, the players in this game are a relative few. Access to production is limited to those who can afford to pay the millions or billions of dollars to bring a new line of service to its customers. Some of these services include wireless internet service, 24/7 on demand satellite-distributed news, telephone calls, electronic mail, radio broadcasts and a broad range of data services. [1]

In previous years, the telecommunication company AT&T had the monopoly over the communications industry. Due to its wealth and strategic global invasion, it was able to bring phone service to a number of countries. With this upper hand in the industry, AT&T was able to control its price and regulate the supply and demand. INTELSAT is the company that modeled after the AT&T domination. Because the satellite market had not been subjected to the rigors of competition, it failed to achieve its potential a few years back. [1] The monopoly INTELSAT had made it virtually impossible for private companies with less spending power to tap into the satellite industry.

One factor leading to the high cost of the satellite market pertains to the repairing of failed electronic components. The current average lifespan of a satellite in geosynchronous orbit is 7 years; after 13 years in orbit, the failure rate is 98%. Also 75% of satellite failure is due to component failure. [2] Some of these electrical components includes the gyroscopes which guide

the satellites to if it deviates and maintain the path of the orbit. Due to the critical nature of this component, failure to repair will lead to the loss of the satellite. Satellite companies usually outsource these maintenances to companies like the Raptor Corporation. Servicing of active and inactive satellites entail component replacement, component repair and component refueling. [2]

Other factors such as launching satellites are also delegated to companies with launching capabilities such as Boeing, Lockheed Martin and Arianespace Corporation. With Arianespace charging between $50 million to $90 million for launching satellites, the market for satellite communication is very limited.

As technology keeps evolving in recent years, production, insurance and launching costs are beginning to mellow to allow for private companies to join in the game. The once monopolistic market is slowing opening its doors to new providers. With the abundance of providers, the services become cheaper and cheaper.

Satellite Communication

Satellites can be referred to as any object that follows a circular or elliptical path around the earth to perform a specific task. This circular or elliptical path the satellite follows is its orbit. There a wide variety of satellites in space all geared at performing a specific function. Some functions are for the weather, communications and broadcast, scientific and navigational purposes. Just a few years ago, satellites were top-secret devices only used for military missions. Its main use was for search and rescue as well as navigational operations. Today, people can’t go a day without seeing the effects of satellite communication. Its uses trickle down to our television programs, our cell phones and car navigations. It’s becoming the cheapest and most efficient method of operating today’s newest technology.

Like many other new products being brought onto the market, there are a number of merits and demerits that have to be weighed before being accepted by the general public. Some of the advantages of satellite communications are:

1. The laying and maintenance of intercontinental cable is difficult and expensive.
2. The heavy usage of intercontinental traffic makes the satellite commercially attractive.
3. Satellites can cover large areas of the earth. This is particularly useful for sparsely populated areas. [1]

Compared to the previous method of intercontinental cable, satellites seem to have a greater advantage. Depending on the orbit it's placed around the earth, they can either cover the entire earth or one specific location. Some of the popular orbits used are asynchronous orbit, polar orbit and the geostationary orbit. Geostationary orbit which is commonly used is about 22,223 miles away from the earth and satellites placed in this orbit remain in the same position relative to the earth. This results in overcrowding and strict laws of 2 degrees of separation among different satellites to prevent interference from each other. Companies that frequently use this orbit are usually global television, satellite radios, press and news agencies and also stock market and financial services. Asynchronous orbits which has an altitude of 3000 to 12000 miles is also widely used for research, tracking wildlife, astronomy, physics and most importantly, the Global positioning system. [2]

Considering all these advantages, it would seem like the satellite industry would be a booming market in this fast developing world. Like any other new product, there are a few constraints that have to be settled. Some of these disadvantages are:

1. Technological limitations preventing the deployment of large, high gain antennas on the satellite platform.

2. Over-crowding of available bandwidths due to low antenna gains.
3. The high investment cost and insurance cost associated with significant probability of failure.
4. High atmospheric losses above 30 GHz. [1]

Every satellite has an antenna specifically to provide gain and to dispose radiation to regions in space. As mentioned above, technological limitations prevent designers from equipping today's satellites with large antennas. Generally large antennas provide high gain and cause no interference from satellites close by.

One of the biggest disadvantages affecting the satellite market are the high investment cost and insurance cost for the satellite to be launched safely and for it to perform its desired function. From the table below, we can see that the insurance for the satellite in orbit is approximately the same for that of satellite construction. This is due to the fact of satellites have a measure of unreliability. There are numerous electrical components that can fail causing immediate repair or total loss of the satellite. The case most common to us would be the failure of the gyroscopes or navigational systems of the Hubble. Satellite or spacecraft is not 100% secure so it is very well possible that $300 million invested in building the satellite can go into flames in a matter of seconds.

Item	Cost [$Million]
Satellite construction	300
Investment finance	300
Insurance	300
Launch	100
	1000

In conclusion, satellites communication is one of the fastest growing markets in this century. Its uses phenomenally exceed that of it's previous to the previous method of communication. Unlike the previous method, there are some very high costs involved and some technological limitations that need to be resolved. Once the general public begins to buy the concept as relatively risk free, its growth would be unbounded.

Future of the Satellite Industry

In order to understand basic feasibility of the man-tended platform concept, one must first know what the future holds for the satellite industry as a whole. For man-tended platforms to have any sort of future, it is vital that the satellite industry remain strong. Fortunately, several corroborating sources present information indicating that the future of the satellite industry is a bright one.

According to the State of the Satellite Industry Report prepared by the Futron Corporation for the Satellite Industry Association, quite a few signs point to the fact that the satellite industry is continuing to grow. In 2004, the commercial satellite industry grew by 6.7%, recording revenues of $97.2 billion, up from $91.1 billion in 2003. Additionally, since Futron and the SIA began recording revenues generated by the satellite industry in 1996, the average annual rate of growth for the industry has been about 13%, with yearly revenue growing to its current level from $38.0 billion in 1996 (Futron, 2005).

Leading the growth of the industry is the Satellite Services branch, which consists of satellite television and radio, along with data and messaging. In particular, Direct-to-Home (DTH) television has continued to be the major driving force behind satellite industry growth, with 10% revenue growth in 2004, while satellite radio revenues grew about 200% from $100 million in 2003 to $300 million in 2004 (Futron, 2005). These trends are quite relevant to the

feasibility of a man-tended platform concept, as continually increasing demand for satellite television and radio will lead to an increased demand for satellites and other space-based products, opening the door for satellite maintenance and man-tended platforms to become a reality.

In 2001, a period when the American economy was still deep in a recession, a Boeing Satellite Systems Senior Vice President, Dr. Ronald C. Maehl, issued a statement responding to concerns that the satellite industry was in danger. In this statement, he mentions the "established markets," using DTH satellite television as an example, along with "emerging markets," where he refers to satellite radio, as two places in which the satellite industry was poised for growth (Maehl, 2001). With a major satellite industry company, Boeing, believing in the possibility for expansion in the future in the fields of satellite television and radio, it seems likely that a man-tended platform could have a potential market.

In a 1997 paper, Cyrus D. Jilla and Dr. David W. Miller speak about past, present and possible future trends in satellite design. One of the currently popular satellite designs about which the authors speak in detail is the SmallSat, a low cost/high risk design. The theory behind this style of design, the authors explain, is that a large number of small, riskier satellites intended for a single purpose will ultimately be less costly than a smaller number of larger, more stable satellites. This design has become virtually universally accepted in the scientific community, another positive sign for the man-tended concept (Jilla, 1997). If this trend continues into the future, and there is no reason to assume that it will any time in the near future, barring a breakthrough in satellite design, then the scientific community could be another possible market for man-tended platforms. The option to periodically maintain these risky satellites would likely be appealing to those who launched them, barring any extreme costs.

In a paper for the 21st International Communications Satellite Systems Conference and Exhibit, P. Takats writes about current and future satellite systems and designs. He immediately points out a major flaw in the way commercial satellites are currently being developed, noting that the idea of launching larger and larger satellites continues to result in increasing costs due to satellite failure. The author goes on to suggest new ways to solve this problem; however, with the advent of the man-tended platform, there would be no need to change satellite design, as companies with vested interest in satellites would be able to periodically maintain all satellites in their possession, as well as have a way to repair any major malfunctions quickly (Takats, 2003).

Case Study Methodology

A common analytical tool for social scientists when determining the usefulness or feasibility of a new idea or product is the case study. Nearly all case studies are designed in a similar manner, which is both well-defined and well-known (Soy, 1997). The five steps typically involved are the following:

- Determine the questions to be answered
- Select the cases and choose the method for data gathering and analysis
- Collect the data
- Analyze the data
- Conclude and prepare a report

The first step to a case study is to establish what question the researcher hopes to answer. This question typically involves a person or program with social or political ties. Knowing what specific question or questions are to be answered gives those doing the research an idea of where to collect the necessary data and what types of analysis will be appropriate. With this step complete, the next is to select the specific cases to be tested and analyses to be used (Soy, 1997).

Step two in the case study method entails determining the cases and analysis methods that will be involved. Now is the time to choose whether to use cases that are typical of those found

in real-life situations or those that are unique to a specific region or set of circumstances. A strong case study typically use multiple methods of data gathering, that can include, but are not limited to, observation, surveys, interviews, and inspection of documents. Data gathered is typically qualitative, but can certainly be quantitative if it better fits the object being tested. Once all methods and cases have been determined, the next step is to prepare to collect the necessary data (Soy, 1997).

The next step is to gather the data. Before data collection can begin, those to be involved with data collection must be notified and informed of the methods that will be used to gather data. Also, researchers should create databases to organize the vast amount of data they will be collecting. Data gatherers must be trained to the specifics of the study and taught to interpret data in a timely and appropriate manner. At this point, actually performing the data collection is simply a matter of following the design the researcher has created up to this point and making full use of all databases created previously. After collecting all data, the research team must analyze the data (Soy, 1997).

Step four in the case study process is to analyze the collected data. The researchers typically categorize the data in as many different ways as possible in order to look for patterns and trends. Specifically, data can be looked at in flow charts and other types of visuals, tables of frequency of occurrence of certain events, matrices of categories, along with many other ways of organizing the data. When patterns arise, the researchers can start to draw conclusions; however, when conflicting data appears, the researchers must go back and dig deeper until the conflicts are resolved. With analysis complete, the final step is to write a report (Soy, 1997).

The final step, when all data has been collected and analyzed, is to write a report of findings and conclusions. A quality case study report displays the complex data in a way that is

fairly simple to understand, so the findings can be presented to a mass audience. Ideally, the reader will have confidence that there are no holes in the research conducted. Reporting the case can be done by giving each case its own chapter, describing the steps chronologically, or as a story (Soy, 1997).

Relating the case study methodology to the idea of a man-tended platform, our goal is to determine the feasibility of such a concept in the satellite industry. Our team will collect data on three separate, yet related cases – satellite television, satellite radio, and satellite telephones. These cases should be effective for accomplishing our goal because gathering data that displays a need for satellite repair and maintenance in all three of these areas will make it fairly elementary to conclude that a man-tended platform makes economic sense.

CHAPTER 3

Satellite Television Providers

One of the most important applications of Man-Tended platforms would be merging the capabilities of companies in the same industry. There are different companies on the markets that produce virtually the same services to their customers. By evaluating satellite based companies and their services, we can group these companies and find how the platform can benefit them. Looking at satellite television providers, there are 3 major players on the market. They are Direct TV, Dish and the new firm Voom. These companies have one thing in common which is to produce television programming with the use of satellites.

For these companies to supply the need of the millions of customers, they currently maintain tens of satellites. The concept of man-tended platforms is the ability to channel all services from these small satellites into one mega satellite. In so doing, maintenance problems as well as the cost of operating the satellites decrease drastically. Launch cost for these three companies would be less than the extremely high cost today. There would be minimal discrepancies involved because these companies are providing the same services.

Satellite Television is like any technology based business. All systems are being updated and renewed as technology changes. Also to maintain the customer need and customer loyalty, new provisions like High Definition packages has to be provided. Hence this leads to the firms launching numerous satellites within a year. Looking at the sea launch history of Direct TV satellite launches, there is an increased number of satellites deployed in recent years than previous years. In 2005 alone, there were four

satellites launched all with the same goal to improve their television services. If all these four satellites launches were done to provide the same goal for Direct TV, Dish and Voom, the cost would be minimal because it would be split three ways.

Satellites are taken out of service if they fail and can no longer meet the standards of the owner. Satellites could fail due to glitchy gyroscopes, draining batteries and other problems. When a satellite is of no more service, its discarded and allowed to float in space as debris. Man-tended platform would be a huge asset in this circumstance because when the satellite fails, it can be easily repaired. Our plan is to have a human inhabit the platform or use launch vehicles for technicians to update and troubleshoot satellites.

Some other commonalities that were found within these three companies were the manufacturers of their satellites and their ground station management. This plays out to be a tremendous benefit for the man-tended platform. If one company oversees the design, building and manufacturing process of the satellites for these companies, the same company can maintain and solve any problems that should arise on the platform. In a Domestic GEO Satellite Inventory as of January 29 2004, LockHeed Martin manufactured the Rainbow 1 for CableVision Systems as well as EchoStar 7 for Dish Networks. [1] If CableVision Systems and Echostar wanted to merge their services to cut down cost, Lockheed Martin could easily build a platform with those 2 satellites because there are basically made of the same components.

From this simple analysis using some outside data, its easy to conclude that a Man Tended Platform would be of great benefit for the satellite television industry. Due to various similarities discussed, cost would be cut excessively which in turn opens avenues for new ventures.