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OVERSIGHT, MANAGEMENT, AND COORDINATION OF SPACE IQP'S

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Abstract

This paper describes the work done to facilitate the communication, management, and oversight of the academic year 2006-2007 space IQP's. The team performed these functions by regularly meeting with other groups, offering suggestions based upon what other groups were doing, and ensuring that the teams efficiently worked around any problems they encountered. In the end, the group was in a better position to offer an overall synthesis of what was accomplished this year than the team members who did the work themselves. As a result, it should be recognized that the outcome of this project is the culmination of the effort of not one, but many teams. The work that all of the teams contributed to the overall endeavor is documented within this report. In addition to the organization of the other project outcomes into one cohesive report, the group dynamics project that has been taking place over the past few years has also been continued. The group dynamics study focuses on the Myers-Briggs Type Indicator cognitive mixes in the groups as they relate to group performance.

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Introduction

This project team was created to oversee, coordinate, and manage several other IQP groups working on projects related to space technology and policy. These teams had been working separately from each other for a term on specific topics when our project began. The mission of the team was to see that there was synthesis, a cohesive picture, drawn from all of the information they gathered and organized. That the whole was more than the sum of the parts.

This paper is structured in the following manner: starting with an introduction of the specific goals of our project and moving on to describing the various groups that we have worked with. Specifically, it is necessary to lay out the goals of those other groups. Next, an evaluation of how well the groups did, using a variety of methods, ranging from personal observations, to advisor input, to surveys taken by the teams. After discussing how well the groups did, we make an attempt to correlate this performance data with the MBTI types of the students in the teams. Following that, there is a self-evaluation to see how well we accomplished our goals, some miscellaneous notes, and finish up with recommendations for the future.

Goals and Methods

This project had several primary goals, each of which had supplementary objectives. What follows is a list of those, as well as a description of the goal in question. Additionally, our methods are discussed, with commentary on how well each goal was achieved.

Communication

The oversight coordination team was initially created to merge the ideas of the various IQP teams working on issues related to space technology and policy. The purpose of this was to see what was learned and achieved in the total effort. Creating a means of communication in which teams would be able to benefit from the information and ideas of other teams was our primary goal. The first term of our project, which was the second for most of the other teams, was devoted to establishing a weekly meeting at which all of the groups would interact. Here the OCM group was hoping to spark connections between groups. For the first few meetings the teams were requested to present proposals of what they hoped would be gained from or produced by their projects; giving an introduction to the topic, as well as a report on what was already completed and what was to be done within the upcoming weeks and months.

In addition to these large weekly meetings, each group met with their advisor weekly. As often as possible, barring any schedule conflicts. One of the best data acquisition tools was to sit in on these more detailed meetings and see what the groups were up to specifically. Aside from obviously allowing more specific data to be collected, this allowed a greater level of trust to develop between the groups. This trust resulted not only from the frequent contact, but also when the a member from the Oversight, Coordination, and Management (OCM) group sat in and were able to be informed about something otherwise not knowledgeable about, corrected about something relayed from a different groups, or provide a completely new source of information. Each of these aspects allowed the OCM group to get closer to the groups and really see how they were progressing, which was critical for the overall project. The biggest problem that the progress of this project faced was that while it was possible to suggest or ask for things to happen, the OCM group had no real authority. Any power gathered over time was due to trust gained from informed influence, and the teams' potential to be useful. Anything suggested could be completely disregarded by the student teams unless their advisor adopted a practice or goal, building a level of trust and making a case for cooperation was essential to the successful completion of the project. It was a rare event when the group was able to influence an advisor directly, but it was possible to involve the OCM advisor to do so on occasion.

The weekly meetings were primarily of use during the first and second term of the project. During the first term, attendance was pretty consistent, and there were new reports each week from one or two teams. These were great times for people to find out more about what the other teams were working on, and several collaborative efforts were spawned as a result. A great example of this was when the team looking into lunar agriculture decided that it was going to need to import nitrogen from an outside source. The team investigating gas harvesting in the Earth's upper atmosphere was considering nitrogen to be a waste byproduct of gathering oxygen. The fact that what was being considered waste was exactly what was necessary to a different potential customer (a customer in a secondary market) that was in need of fertilizer, not fuel, and neither producer nor consumer were talking to outside sources. Once the two spoke with each other, the LEO gas harvesting team realized that not only were they not going to throw away their "waste," but they could potentially make a profit off of it if it was delivered to the Moon. Hence, they focused on storage and called for a more advanced delivery system. Additionally, the teams working on lunar development and lunar agriculture had an ongoing discussion about how much shielding would be required for a settlement, with one saying as little as eight meters of regolith piled on top of any settlement would be sufficient, and the other claiming that as much as 40 meters would be required. The shielding was a major issue for both teams. The lunar development group wanted to ensure the safety of the inhabitants and the equipment being stored underground, while the lunar agriculture group wanted the easiest access to light. Sadly, they never were able to come to a conclusion on either what would be enough to block 90% of the hazard, nor under what circumstances 90% protection would not be sufficient. However, the Agriculture Team made a persuasive case and moved on. The Lunar Development team was hung up on the issue and carried over to the next academic year. Overall, the first term allow the OCM team to establish its right to be involved and contribute to the success of the teams. The effort was worthwhile considering the door it opened to cross team information during the following terms.

The second term of the project started with preparations for the annual International Association for Science, Technology, and Society (IASTS) conference to be discussed in more detail in the next section. The teams that were presenting at the conference performed "dry runs" of their presentations. This was to ensure the teams knew, in its entirety, what they were to be discussing prior to presenting at a major professional conference. These preparations were unavoidable and necessary, as the conference was the fourth week of the term and many of the teams had never presented their studies in front of an audience. There were three weeks for four teams to present to prepare the members for what they would encounter at the conference.

Unfortunately, due to the fact that the group was forced to focus almost exclusively on the IASTS conference in the weekly meetings, the teams that were not presenting lost interest in the meetings. Despite the efforts to regain these members in our meetings, they were repetitious and their attendance suffered. Regardless of the desire to keep track of where the teams were in their respective projects, they were not coming to do the short weekly update that been useful. Had they continued attending, they would have been able to provide valuable feedback regarding how the team's presentations were coming. After the conference, there was one additional meeting to wrap up what was done, what was learned, and what might be done differently in the future. This would wind up being the final meeting, because the general consensus during the write-up phase was that the meetings were at this point becoming more of a chore than a help to anyone but the OCM group. As a result, there was an increase in attending individual meetings with the groups and their advisors. There was no other option considering the poor attendance and that the most troubled groups avoided the weekly meetings.

In the final term it was decided that for the benefit of anyone who was not able to attend the Baltimore IASTS conference, as well as the general WPI community, the OCM group would hold a conference on campus to promote communication about space technology and policy. This is to be discussed in further detail in the subsection entitled Pugwash Conference.

Baltimore IASTS Conference

During the academic year of 2006 - 2007 six of WPI´s IQP projects had the opportunity to present their work at an international conference in Baltimore, MD. The conference was organized by the International Association of Science, Technology, and Society. The IASTS is an organization concerned with the relations between science, technology and society, with an emphasis on the societal impacts of technologies. The annual conference has presenters from all around the world from a variety of fields including engineers, professors, environmentalists, ethicists, and policy analysts. The 2007 IASTS conference, which was the 22nd annual IASTS conference, was held in Baltimore, MD in the Radisson Plaza Lord Baltimore. The conference lasted from Thursday, February 1st to Saturday, February 3rd. One the WPI Thursday presenters' was Nathan Tibbetts, presenting The Pakistan Connection: a New Historically Grounded LRGP. The presentation was not about space but outlined the project that Nathan was working on. The Pakistan Connection is a role playing game (RPG) centered on nuclear proliferation and is made to be used in a classroom setting. The game requires groups of students to represent various countries including France, Pakistan, England, Russia, India, South Africa, Israel, China, Iran, United States, and North Korea. Each student is provided with a role for their country, for example Nuclear Physicist or Political Advisor. These "representatives" are gathered together at a mock meeting of the International Atomic Energy Agency (IAEA) trying to reach a compromise of how much power should be delegated to the agency. This debate was sparked because of the IAEA failing to control nuclear proliferation with only its limited power.

Laura Handler was the second Thursday presenter from WPI. She graduated in May 2006 but had been very involved with the continuation of her IQP from 2005. Laura presented Which Professions are "Okay" to Aspire to? Perspectives from High School Girls. During the time spent completing her IQP, Laura conducted a survey to 1006 juniors in the

Worcester Public School District. This survey, which was distributed to 64% of juniors enrolled, was to investigate the careers that male and female students were aspiring to. The survey results showed that males and females do in fact have different patterns of interest. In fact, the data showed that the females were dramatically more likely to be interested in professional careers, for example doctors, lawyers etc., than males. However, there was a minimal amount of female students interested in engineering. This was confirmed by a continuation of the project in 2006 by a replication team of WPI students gathering and evaluating eighth grade, sophomore, and junior student interest data. The 8th grade data was different from the 11th grade data as the boys and girls were then quite similar but by 11th grade that had changed. It was clear that something needed to be done to stimulate interest among female students. Therefore, two programs were implemented in the school districts. One was to encourage 11th grade females to pursue careers in engineering. The other was a 9th grade Future Scientist and Engineer Club, which was not restricted to females but disproportionately attracted them. These programs showed promising results and increased the interest in engineering careers considerably.

The other projects that were presented include the titles: Gathering Gases in Space for Sale, The Challenge of Growing Potatoes on the Moon, and The Effect of Cognitive Preference on Forecasting Space Technologies. These project groups presented for 15-20 minutes on the same material that will be later discussed further in depth.

In addition to the already mentioned responsibilities of the OCM team a presentation opportunity arose for the IASTS conference. Some projects that were completed throughout the 2005 - 2006 academic school year did not have teams continuing their studies the following year. These projects include a Helium-3 team that looked into the probability of He-3 as an energy source of the future. These studies set the stage for the others indirectly and would shed some light upon what could be a unified aspiration to further aerospace technology developments. One of the team members from the OCM team, Elizabeth Villani, decided to take on the challenge of presenting "The Energy Crisis, Helium - 3, and an Earth-Moon Trade System." using support from the past He-3 project. The presentation discussed general information regarding He-3 as well as discussing its possible impact as an energy source. There was also the topic of developing a trade system to bring He-3 from the Moon to the Earth in trade for hydrogen which was needed on the moon. A summary of the presentation is below:

As the worlds energy requirements continue to increase, so does the need for alternative energy sources. Scientists have turned to nuclear energy as a possibility in meeting the growing demand. There is an isotope called He-3 that is located within the regolith of the Moon that is the ideal fuel for nuclear fusion .What makes this gas different from normal helium is that it consists of two protons and one neutron instead of two protons and two neutrons. There is a very limited amount of He-3 on Earth, all of which is man-made. It is either created by scientists, or is the byproduct of nuclear weapon maintenance. The reason this gas is not present in our atmosphere is because of the Earths' magnetic fields. He-3 comes from the sun, propelled by solar winds, but is deflected from the Earth's magnetic fields and then to be carried into space. Some, though, is absorbed into the lunar surface due to the lack of a magnetic field surrounding the Moon. There is a high concentration (about 50%) of the Moons' He-3 is located in the lunar maria, which are the dark basaltic plains that make up 20% of the lunar surface. However, because of meteorite impacts He-3 can be found up to several meters deep in the regolith. There is an estimated 1,100,000 tons of He-3 on the Moon. In order to extract it, the regolith must be heated up to 800 degrees Celsius. Also, when attempting to extract the He-3, you will gather other gases including the elements carbon (which can be used for manufacturing), nitrogen (which can be helpful in agriculture), and oxygen (which can be used to make water when combined with hydrogen), among other things, like rocket fuel.

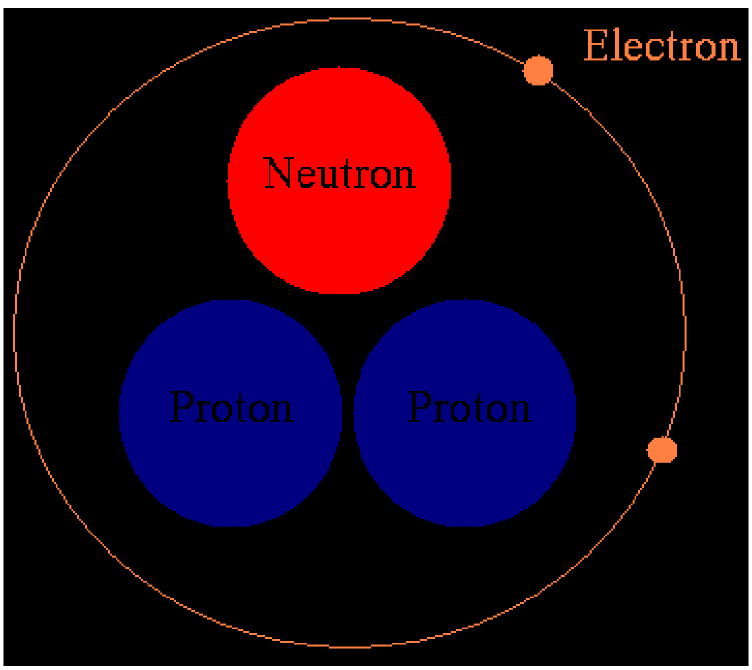

Diagram of Helium-3

Steps have been taken already to be able to master overall fusion to create an alternate source of energy to replace current fossil fuels. There are many advantages to converting to fusion energy over not only fossil fuels but fission nuclear power as well. First of all, there is an abundant supply of the needed components for fusion. Current experiments are being done with lithium and deuterium. Lithium (which produces tritium) is found in light metals within the Earths crust. Deuterium (an isotope of hydrogen) is extracted from sea water. Since these elements are readily available in a large quantity and basically inexhaustible the cost is low. Recently, prices for fossil fuels have been increasing rapidly, and this trend will only continue as oil and coal becomes scarcer. If energy is continued to be used as it is today (with 85.5% of energy consumption coming from fossil fuels) with all known reserves accounted for, it is possible to run out of these resources within the next 100 years. It should be noted that He-3 is much more difficult to make fuse than deuterium and tritium are, as outlined in prior IQP's.[1] Taking an optimistic viewpoint, it is still conceivable that it is possible to do. Provided with a cheap fuel source and theoretically high efficiencies, engineers will certainly try to find a way around all the problems presented to them, however many decades it may take. The eventual prize is worth the time and determined effort.

In addition, fusion reactions do not emit green house gases which deplete the ozone layer, as well as having other harmful additional effects on the environment. Therefore, fusion is a relatively clean energy process. Contrary to what most people think, fusion reactions are actually very safe. Any sign of a malfunction will cause an automatic shutdown; a meltdown, which is one of the drawbacks to fission, is not a possibility. There is also a very low risk of radioactive emissions on surrounding environment, and since fusion can be used in large scale production it can be used safely in cities. Since fusion creates very little radioactive waste, 99% of energy released is charged particles which directly convert to energy, leaving only 1% to become radioactive, only the material located close to the fusion plasma will become radioactive. Given the fact that the interior of the reactors are approximately the size of a basketball, there isn't very much material to begin with. In addition to generating very little waste, what waste that is produced will be able to be disposed of safely within a few decades. The radioactive waste emitted from a fusion reaction has a very short half life. Fission, on the other hand, has a very large amount of radioactive waste that takes thousands of years to decay. Since there is minimal

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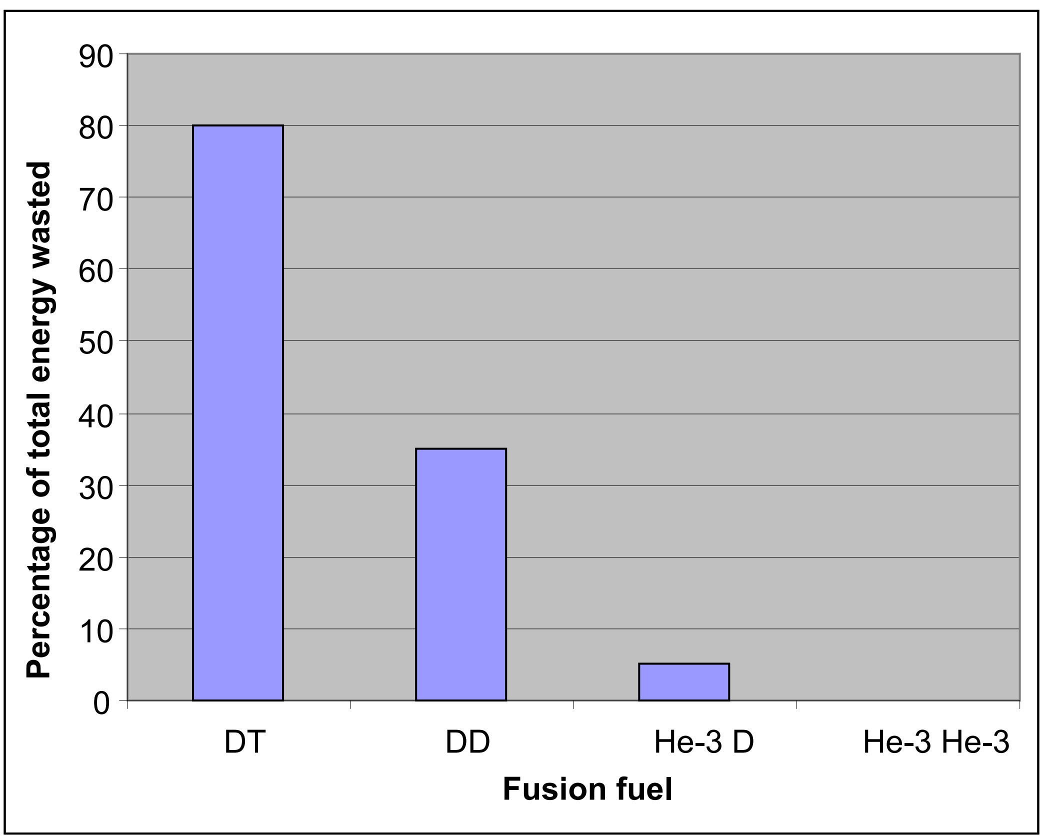
[1] Carino et al.

and short lived radioactive waste produced from He-3 energy, this opens up a whole new world in regard to powering spacecraft, as well as interstellar travel. The reduced radioactivity means that less radioactive shielding is required. That lightens the load of craft, which in turn lowers travel costs. The cost to commercially lift one pound into space using conventional means is approximately $10,000.

The graph below shows the relationships between the reactions and their production of radioactive waste. Clearly the He3-He3 reaction is the best choice when considering this. With all of the advantages of nuclear fusion there are also some disadvantages. Fusion is very difficult to achieve, considering the extreme temperatures and pressures involved. Also, the components are more complex compared to conventional nuclear energy generation. It is necessary to constrain the materials by electrical or magnetic fields since no known material can withstand the required temperatures. There is also a going to need to be a great deal of development time for the large expensive facilities. Fusion reactions are still undergoing tests. Current development is underway of the International Thermonuclear Experimental Reactor, known as ITER. The final designs of the ITER were completed in 2001 and the first plasma production is anticipated by 2016. Also, the Department of Energy is focusing on the easier types of fusions which are D-T and D-D for now. This is a mistake, since concurrent work on He-3-D makes sense given the plan that exploration of the Moon will resume around 2020. This plan supports the research of a He-3-He-3 reaction considering the Moon inhabitants will need an energy source.



Everyone has noticed the prices of fossil fuels sky rocketing over the last few years, and with no end in sight we'll need to brace our bank accounts to prepare for these escalating costs. The projected costs for He-3 are phenomenally lower than that of oil and other fossil fuels. Currently, the United States uses 25% of the world's energy every year with only 4.6% of the world's population. The fact that only 25 tons of He-3 would power the United States for a year is incredible. This amount would probably be a single spacecrafts load.

A lunar base with accompanying transportation is a necessity for a functioning mining venture. To have a lunar base or colony would not only give us the control of the previously mentioned resources but also create an environment where technology could readily advance. The natural vacuum environment, instead of man-made vacuum situations, would create a setting where experiments, that would be expensive and extreme on earth, would be able to be accomplished. Also, the Moon is only days away from the Earth, which would allows travel to and from easier and cheaper. The time delay of sending electric signals is a very short 2.5s, whereas messages sent to Mars take approximately 15 minutes, so telecommunication would be relatively easy. The Moon is actually a big chunk of Earth that was broken off when a Mars-sized object collided with the Earth. Therefore, the majority of its compounds and elements are the same as those on Earth and scientists already have knowledge of how to use them.

The presentation in Baltimore also included a lead-in to the other projects being presented. Those projects will be discussed in their own sections, however, so the information will not be repeated here.

"The exploration and use of the Moon shall be the province of all mankind and shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development. Due regard shall be paid to the interests of present and future generations as well as to the need to promote higher standards of living and conditions of economical and social progress and development in accordance with the charter of the United Nations" (Office for the Outer Space Affairs, 1967)

This is an excerpt from a UN treaty discussing property rights on the Moon. It states that no nation or country may claim outer space or any celestial body as its own territory, but allows for the use of resources provided that any wealth obtained is to be distributed to all the nations of the world. This treaty was created to set the stage for claiming property and resources, but loopholes do exist. It is possible to obtain mineral rights of celestial body. Also, space law does not allow countries to have land ownership but does not directly restrict individuals or companies, though it does make their nations responsible for their actions. There are already Moon areas claimed for mineral rights, by individuals or teams of scientists. A team that holds majority of the lunar mineral rights is holding them to allow for the extraction of He-3. Other materials for the advancement of Space Exploration, Earth and Spaces Sciences are also of interest, though safer more efficiency energy production would by itself justify lunar resource extraction. This shows that the race for space resources has already started.

The ability to create a new viable energy source that is cheap, efficient, clean and abundant would allow to world to overcome the current energy crisis. We're running out of energy and may have the perfect solution to our problem right above our heads. Is it possible that He-3 could just be that energy source? Is it possible that the Moon could be the future equivalent of the modern day Persian Gulf? This is a real possibility, and one that may not be more than a century away.

The IASTS conference provided an experience for undergraduates to present the result of their research publicly to persons of various backgrounds and a level of interest. The ability to speak well in public is an important business skill. The groups that presented are now aware of the effort and preparation necessary to complete a successful presentation and will hopefully find it less challenging the next time they give a presentation as a professional. The groups that presented were among those that were the most successful of this year. They were selected because they were promising, but turned out to be more than that. The teams were forced to focus on their main points and outline what their projects were all about. This entailed the teams diminish all ambiguity and tie up loose ends well for the presentations, this was months before the deadline of the final write up. As a result these groups had higher quality reports, and were more likely to finish on time

Aside from boosting their own personal skills for the future, the conference provided direct benefits to the presenters. They were forced to organize their ideas in a way that could be presented to a group that had little to no background with the material. This turned out to be a great help when writing up the final reports. Also, those groups who presented in Baltimore had their presentations ready for the next term, when the Oversight, Coordination, and Management project group sponsored a conference with the assistance of Student Pugwash and the WPI

Office of Admissions. This conference was to exhibit the projects for local High School students and the WPI students

Pugwash Conference

Towards the end of the project, an opportunity arose to join forces with the WPI organization known as Student Pugwash. Pugwash is an organization concern with the social implications of technology. The opportunity came in the form of a conference sponsored by Pugwash for the IQP groups involved with space technologies to present their projects. This chapter of Student Pugwash is conveniently advised by Professor John Wilkes, the advisor of not only the Oversight Coordination and Management Team but many of the other space technology IQP´s. Also, Elizabeth Villani who is one half of the Coordination Management Team is the President of Student Pugwash. This created the perfect foundation of organizational support to successfully plan the event. The conference began as a suggestion from Professor Wilkes. He had made his case by stating that the conference would be a valuable way to wrap up the year and give insight to the current state of the projects. The local exposure would increase the odds of the continuation of the line of research laid out this year and provide interested students with a base of knowledge about what had been done in the past at the beginning of their projects the next year

In addition to an event for the WPI audience there was also another outreach opportunity in the form of a group of IQP teams, known as the Club Team. The Club Team had been working with 5 of the local high schools to establish after-school "Future Scientist and Engineer" clubs for students of all levels that have interests in math, science, and technology. The high school students were required to attend a certain number of club meetings before being permitted to visit WPI for the day as a field trip. The students started with a talk by admissions and a campus tour and then spent approximately two hours sitting in on the space presentations. Having the High School students participate with the conference would support their interest in upcoming technologies and also would help to advance the cause of science and technology as a career possibility. The perspective and feedback of the students in relation to the probability of certain "breakthroughs" was also of interest. In the end approximately 75 high school students, 15-20 from four of the five schools, were able to attend. One school had a conflict; there were approximately 100 people in total attending the conference. This number does not include presenters and organizers.

The conference was planned to start at 11:00 am and finish at approximately 2:30pm on April 4, 2007. The High School students would only be able to remain at the conference until 1:00PM; this was because of the transportation. The presentations would be approximately 15 minutes in length including a question and answer session with a short lunch break at noon. Sandwiches would be provided to those who were sitting in on the conference and were to hopefully entice more WPI students to enter. In order to hold the conference presenters were essential. The OCM team presented the idea of the conference to the current IQP teams and received a mixed reaction. Those groups that were comfortable with their material and the understood the obligations as presenters were easy to recruit. The rest were more difficult to persuade into volunteering and in most cases the advisors were not all ready to support the idea that preparing for a presentation should take priority over the writing of the report. Still most students worked together with the OCM group to create a schedule of events around the class schedule of those groups that were available.

While receiving confirmations on presenters planning for the people estimated to attend started, including the financial estimates. The OCM team estimated that there would be approximately 120 people attending the conference. That meant 120 people would need lunch to be provided for, as well as transportation for the high school students to the WPI campus. The Student Pugwash organization was very generous and offered as much coverage for the price as possible but we found that the price of the lunch exceeded their budget. In attempts to cut the costs the team looked towards Admissions to pay for as many of the student meals as possible. In the past that when high school students were coming to visit WPI admissions would pay for their lunch as long as the students completed a campus tour with one of the Crimson Key tour guides.

Working with Admissions, it was found that they would not be able to provide the full coverage of the cost of the lunch buffet that was initially in mind. Admissions usually provides pizza and not sandwiches for visiting high school students. It would not be fair to the other student organizations that had asked admissions for cost coverage to make any exceptions. So requested from admissions was the equivalent dollar amount that they would spend on pizza for the students to be used toward the cost of sandwiches. The compromise allowed admissions to write Student Pugwash a check for the allotted amount and therefore lunch would be able to be provided for all those attending the conference at a price we could afford. The second issue at hand in terms of expense was transportation of the high school students. Two buses were needed to pick up the students each of an initial cost of $300.00 per bus. Student Pugwash was able to provide the funds for one bus while the Club Teams needed to search for the funding for the second. However, with further research into the costs of the transportation it was found that it cost half of the initial estimate and that each bus was only $150.00. This allowed for Student Pugwash to ensure the transportation of the students by footing the whole bill. This was a fortunate error since the Club Team failed to write a proposal with sufficient cost justification to get funding.

In addition to having the outside audience, two professionals were invited to come in and actually present and participate in the conference; they were Dr. Diana Jennings and Joseph Palaia. Connections made through the IASTS Conference in Baltimore that was previously mentioned allowed for us to arrange Joe Palaia to become involved. Joe Palaia is the co-founder and vice president of the 4Frontiers Corporation. He was brought in to provide some insight in regard to the value and quality of the WPI space projects as a whole. The WPI teams had all been doing work focused almost entirely on the Moon as the primary goal in the near future of space exploration. 4Frontiers is mainly focused on Mars as a means to create a homestead. Joe presented the ideas of his company in terms of technicality, living arrangements, and type of people who would be recruited to start the colonization of Mars. Thus he was a knowledgeable potential critic. If he were to present his case, perhaps similar problems could be examined between the different mind sets and both sides could potentially benefit from the exchange of ideas. More details of this presentation will follow in a later section.

Dr. Jennings was the Associate Director for the NASA Institute for Advanced Concepts, or NIAC for short. The project group, known as NIAC, was sponsored by her and she was a close contact throughout their project the past year. In particular she helped the team recruit their panel of evaluation for the Delphi study. When she was informed of the conference by both the team and Professor Wilkes, she jumped on the opportunity to get a first-hand look at the results of the team she had worked so closely with. She even volunteered to speak at the conference and was primarily tasked with being the discussant and commentator on the whole conference, reflecting on what had been presented, what needed to be improved, what was being done well, and what was missing entirely. Her experience in the field made her an invaluable source to better understand the probabilities of the development of not only the IQP projects but of the 4Frontiers Corporation mission as well. On the other hand, she also came to share some bad news. NIAC funding was cut for the first time in nine years. Therefore, there would be no NIAC team next year at WPI. However, Dr. Jennings commented that she would still help recruit panel evaluators from the existing pool of NIAC fellows.

Although the conference allowed for the OCM team to listen to the work that was being completed by the students who had not presented in Baltimore, it did not provide the necessary details that had been hoped for. The time allotted to each of the presentations was not enough to go into detail about complications of the project and how they were overcome. The fact that some of the presentations needed to be "watered down" for the high school students (some of whom had never taken a physics class) may have affected the complexity to which the IQP students discussed certain topics. Overall the conference was an interesting experience of combining people of all intellectual levels to come and listen to what could become future technology. In retrospect, working around the WPI class schedules should not have been our major priority in scheduling the presentation times. In the end, some of the best presentations were given after the High School students had left. Also, our lead presentation when the students had arrived was an unknown quantity- a team that had not presented in Baltimore and clearly not practiced in advance. In the future, organizers should not schedule a team that had not performed “dry-runs” of their presentations. In addition too much time was spent to clarify questions that the high school students may have had in regard to fusion technologies, this caused the conference to run behind schedule. The presentation by the OCM member given in Baltimore should have been repeated or at least co-presented to give the necessary information and added energy for a successful presentation. Fortunately the following presenters were from a group that had presented in Baltimore and were able to recapture the momentum. They were smooth, sharp, energetic and on schedule. By contrast, the “Do Space” project on career opportunities in space for everyone, not just astronauts and engineers was scheduled after the High School students had left. This should have been the lead off presentation to capture the students’ attention and have them think of the following presentations on a more personal level.

The scheduling problems of the conference are not to be laid on the shoulders of the OCM group alone. The Club Teams had not provided adequate information regarding their scheduling constraints and had not assisted in any of the conference planning or funding. This being the first conference held to exhibit student studies in space technologies allowed Student Pugwash, as well as the OCM group, to learn a great deal in regard to coordination of multitudes of teams and outside involvement.

Overview and Synthesis of the Results

This part of the project is what could be considered to be our single most important goal. Once the other teams have each done their research and drawn their separate conclusions, what does it all mean when it is put together? Of course, this is also the part of the project that is most reliant upon the other team's success. If only one or two projects are truly successful, it would be unrealistic to try to form an idea of what should be concluded from it all. On the other hand, given nine teams in addition to the OCM team, even if only half did a decent job, it was be possible to integrate the results. It turned out, as will be shown, that the teams that finished tell at most half the story. The 2006 – 2007 initiative is already a qualified success and sets the stage for exciting extensions next year. Still, it is by no means the pinnacle of the whole initiative, with a clear conclusion based on 25 projects completed over three years, as it was hoped it might be.

Correlating Personality Type and Team Success

The final goal for this project was to correlate the mix of personalities on the teams with the eventual level of success of the teams. This was done by means of using the Myers-Briggs Type Indicator (MBTI). The MBTI assigns each person a four letter code based on their personality. Each letter can have one of two values, meaning there are a total of 16 personalities. This data collection was a large portion of the project, it will be given a full section later in the paper, where the indicator used will be explained in greater detail, and the results reported.

Team Missions

In order to aid the project groups for the 2006-2007 academic year it was necessary to understand the objectives of each group. As mentioned previously in the communication section, through the weekly meetings the OCM group was able to interact with the various groups to envision an overall goal. Also utilized were the final papers from each group as they were submitted to the library. These resources were able to provide the OCM group with the information necessary to formulate the mission of each group, what they learned in trying to reach it, and how they evolved for their intended goal.

Lunar Agriculture

The first group to be discussed will be the lunar agriculture team. This team consisted of Benjamin Moody, Christopher Songer, and Robert Groezinger with advisor Professor Wilkes. To their advantage an additional advisor was added to the team, inventor Paul Klinkman who was a class of 1976 graduate of WPI. The team was interested in creating a means of agriculture to support a self-sustaining lunar colony. The ability to provide food and water would need to be mastered before inhabitants could permanently live in a sustainable base. The Lunar Agriculture team chose potato plants (as well as yams and similar tubers) as the possible food source that they would research to grow on the Moon. This choice was based on the facts of the durability of potatoes in various climates and its high vitamin content. Another way to provide nourishment included an Earth-Moon or interplanetary trade system to provide the Moon with all the essentials for living. Starting with the idea of using a Bionic Leaf (breakthrough required) that could function on the lunar surface, they met with Paul Klinkman to brainstorm alternatives. They come up with the much simpler approach of an underground greenhouse. Working with that idea, the group added that missing link to conceive of a viable agriculture system. That did not require a breakthrough but also considered how valuable it would be to have a bionic leaf later.

NIAC

A project entitled Effect of Cognitive Preference on Forecasting Space Technologies was completed by a group that worked closely with the NASA Institute of Advanced Concepts to recruit expert reviewers and ultimately create their project Delphi Study. Their involvement with the institute caused them to be called the NIAC team within the WPI community. The team consisted of three WPI juniors: William Flaherty, Michael Monfreda, and Oana Raluca Luca. The NIAC project was a continuation of past IQP groups which had a similar objective. The NIAC group made technological forecasts based on something known as the Delphi method. The Delphi method is technique of obtaining data from respondents regarding the likelihood and significance of given technological advances.

The 2006-2007 NIAC team decided to vary their methodology slightly from the past projects use of the standard Delphi method. They used two waves of questionnaires. The first was a breakthrough questionnaire, asking probability of 20 individual technologies. The results were then compiled into scenarios and sent back to the experts, who were then asked to reexamine the same ideas in combinations, so that, in the words of the IQP team, “they are given the option to either defend the composite opinions of the panel or change them.”[2] In the standard Delphi method, the feedback would not be a composite, but just a distribution of responses and the participants who were “outliers” would be asked to defend or change their ratings.

How High How Fast

The next group to be discussed is the How High How Fast (HHHF) group with team members Brian Kolk, Brenden Malloy, and Thomas Huynh advised by Professor Wilkes. This group was a follow-up project from the prior year. The previous year, another team had concluded that it was not economically feasible to have a spacecraft come from orbit, dip into the atmosphere, collect gasses for propulsion or other uses, and then re-achieve orbit. In fact, it would probably use more fuel than it produced. This year’s team was supposed to either verify their findings, or provide an argument saying that the prior team had made an error and specify the nature of that error. They ended up working closely with an outside inventor, Paul Klinkman (who eventually became their co-advisor). Klinkman felt that the prior year’s team had been operating under an incorrect assumption, which led them to incorrect conclusions. The assumption was that the makeup of the Earth’s atmosphere is constant relative to altitude. That is, they expected that it would be about 80% nitrogen, 19% oxygen, and 1% other gasses both at sea level and at 200 km, the edge of space, and too thin to be of interest higher than that level.

This finding was controversial, and not all were convinced that the goal could not be achieved. Hence, the new team was initially formed to see if one could compensate with speed for the lower density and not dip as low into the atmosphere. Klinkman’s data took that one step further as he reported that at higher altitudes, such as 400 km, the gasses tend to settle out due to their differing densities. This produced layers of mostly nitrogen, oxygen, helium, and hydrogen making it much easier to target specific gasses for harvesting. For example, if one wanted to harvest more oxygen, to be used to refuel spacecraft with LOX once they reach orbit, one would go to where oxygen was naturally the predominant gas. Of course, the system is not perfect, and

[2] NIAC Paper Reference

other gasses would be gathered while the 85% oxygen was the target, so they would then need to cool the gasses so as to further separate them from each other by their different liquefaction points.

Additionally, because gravity gets weaker the further from the Earth, there is less gas per volume of space up at the higher atmospheres. This means that the spacecraft would have to be very big and going very fast in order for it to collect a reasonable amount of hydrogen gas in a year. Oxygen looked feasible with a 30 meter "scoop" at normal orbital speeds of 17,000 mph. At the same time, however, the group is trying to collect gasses, so using their own product up to gather more is to be avoided, and at some point self-defeating. Hence, another method of propulsion should be used. The use an electro-dynamic tether to counter the drag was proposed. Finally, the team needed to figure out a way to not only stay in orbit and collect, but then also distribute the gasses to their customers. It was a challenging technical problem calling for a feasibility study.

Space Station

The group working on the possibility of the International Space Station (ISS) ever paying for itself was comprised of members: Devin P. Auclair, Fitzgerald J. Huang and Christopher Ivory. This is significant because if the ISS can pay for itself, it means that other space stations, and space ventures at large, are able to become investments rather than experiments. The ISS was not intended to be a commercial venture at the outset, so if it is able to break even, or somehow turn a profit, it would pour $20 billion back into government, hopefully NASA, offers for other projects. The Space Station team looked into various methods of having the ISS accomplish this goal, including using the station as a staging area for spacecraft going elsewhere in the solar system, ongoing scientific pursuits, and other uses, but it was in the wrong place to be a good point of departure for the Moon or Mars. It is only suitable as an orbitary laboratory. To be cost effective for that use it was 20 times too expensive. However, a station like Skylab, launched in one piece, could have paid for itself. One of the problems was the cost of construction in lower earth orbit.

New Space Initiative

The New Space Initiative (NSI) team was a group consisting of four students: Katie Elliot, William Treese, Derek Pszybysz, and James McClintock. Their project entailed two objectives: to essentially question the next generation of United States public in terms of its view of space activity and better understand the attitudes and information base associated with political and financial of support for NASA and space exploration. They looked to evaluate the current state at which the United States stands in the race for territory in space against the Peoples Republic of China starting with researching the competitive history between the two countries. When the age of technology super powers began the top experts were the United States and Russia. However, the Chinese National Space Agency (CNSA) has now obtained nearly all of the Russian technology. This allowed the CNSA to catch up very quickly to the point where they could actually become the leader in space technology in a few years. China has been focusing on the Moon which would require a space craft to endure a 3 day trip, one way, while NASA is focusing on Mars which requires a space craft to endure a one way trip of 6 months. As NASA spends more and more time developing this extremely advanced technology for a far region of the solar system it could be possible instead to update and perfect current technologies to be ready for the upcoming space race to the Moon. The rapid advancements made by the CNSA could form a potential threat as rumors circulate of Chinese colonization of the Moon and practices targeting satellites. NSI aimed to understand and document the role of public perception and support of space travel in the United States history and possible future of space.

In order to estimate the level of public support that NASA will have for building a Moon Base and related infrastructure about 2020-2030, when it is actually in the process of building one, the NSI team surveyed both high school and WPI students. The NSI group gathered data at two Worcester city high schools and one in rural Pennsylvania. The two groups of students at two different levels of education would be compared to see if background knowledge is important in shaping opinion. The group seemed to think that in a technically-oriented college population there would be an increased level of support. Since the WPI population represents a "technically literate" part of the American population, it was interesting to compare them to a less technically inclined population. The high school students would be less self interestedly biased in favor of a big technology initiative and be a better representation of the general public. In order to assess the knowledge variable and standardize the information that the high school students may have had the study design was as follows: an initial survey, information session and/or handout on Helium-3 and the Moon, and then re-administering the initial survey.

Considering the general public resists unjustified change, the group hypothesized that after the information session, support would increase as a “better” case for a lunar base would have been made. On the other hand, they were also aware of the theory of selective perception. This theory involves people selectively retaining only that new information that fits with their pre-existing opinion, and thus strengthening their case for it. Thus, the outcome was not clear since information by itself does not change opinion, unless it affects underlying attitudes and perceptions as well. Still, they expected to see some positive change and tried to measure some relevant perceptions of the Moon as well. The value of public support rivaling that of the US-Soviet Moon race Apollo missions in the 2020 time period was clear enough. The question was whether NASA was likely to get that kind of support from the citizenry that would be voting adults at that time if a case for a Moon base that mentioned resources such as Helium-3 was made to them.

Fusion

There were actually two teams doing research into the feasibility of fusion power in the coming decades, one of which we tracked more closely at the beginning of their project, the other more towards the end of it. Fusion power is critical for space issues for many reasons. First, if fusion power is mastered, propulsion using fusion comes out of the realm of science fiction and into reality, allowing significantly reduced travel times relative to conventional drives. Secondly, a fusion power plant offers much higher energy density than a fission or solar plant, the only real alternatives on the Moon.

Nuclear power of some kind is the only other reliable alternative to solar power for spacecraft and space settlements, and fusion is superior to fission if we can master the process. Certainly no one is going to set up an oil or coal-fired power plant on the Moon due to the high cost of transporting fuel off of the Earth and to the Moon, though hydrogen or fuel cells are likely sources of power for transportation. Fusion power on the Moon becomes a realistic because of the supply of Helium-3 located on the Moon.

He-3 is theoretically able to be used in a fusion reactor, and can have an extraordinarily high efficiency of conversion to electrical energy. The result, therefore, is that if a working fusion generator were set up on the Moon, the base would have an essentially limitless supply of energy. Fusion relies upon Einstein's $E=mc^2$ relationship, and c is a very large number, thus giving a large amount of energy per gram of material used.

The two teams focused on different kinds of fusion power. The first team was looking into He-3 as the fuel source, while the other team concentrated on that is really currently being researched on Earth now, a process using deuterium and tritium (two different forms of water with one and two extra neutron in the nucleus, respectively) to power the generator. Both, however, were trying to assess the difficulty of having fusion as a primary energy source in space and on Earth. The He-3 focused group went one step further speculating on the implications if He-3 could be gathered on the Moon and be transported back to Earth to be sold cheaply. Thereby eliminating the Earth's energy crisis and setting up a trade system in which a lunar colony could pay for what the Moon dwellers would need to import.

This study was also tied to the Delphi study being done by the NIAC group as one of the items reviewed by the expert panel involved a Fusion reactor. They explicitly grounded themselves in the literature on this subject and then evaluated the item as the panelists had been asked to do. After offering their ratings they wrote 2-3 page rationales and compared their views to those of the expert panelists. In combination, the two sources of information were revealing and a cause for cautious optimism about our having a working fusion reactor on Earth in the next 30 years.

Drives

The Drives group also based their project topic on past Delphi panel "breakthrough" studies. In this case they looked into the three most popular of the technologies in the drives section. Again they were to immerse themselves in the literature and see if they rated these technologies more like the experts or the typical WPI students after looking into the subjects in detail. However, with three technologies to be covered by 2 people, one does not get three separately justified ratings of the same technology. There was a division of labor in the group on data gathering and then a group position that comes out of their discussions with each other in which they were not equally grounded in each drive's technology and challenges.

Nicholas Cummings and John Schneeloch, the two members of the team, evaluated some of the more promising technologies in the drives section. They wanted to conduct their own study, similar to the results of the NIAC Delphi method, with regard to significance, probability, likelihood, and estimated time of development. Each of the technologies was also to be rated based upon various factors such as speed, efficiency, operating cost, development cost, and suitability to a given task. Of the drives available, the students took an interest in alternative drives to the current chemical rockets. These include nuclear drive, electric propulsion, and the solar sail. Nuclear drives are drives using nuclear reactors used to heat either a liquid or gas to extreme temperatures to expand. The increased volume is what propels a unit forward. Ion drives makes use of magnets to accelerate the speed of ion gases. A solar sail is a thin film that uses radiation such as light rays from the sun to be propelled forward.

An interesting outcome from this group was a detailed critique of the items in the Breakthrough survey dealing with why an expert in their field would have been disoriented or bothered by some of them. These comments pertaining to some interesting methodological questions were suggesting that it would have been well to have gone into each technology at this level of detail before constructing the Delphi instrument. Of course to assign one person to each of 21 technologies would have consumed the project of a group of 21, rather than three, students that developed this survey.

Moon vs. Mars

The Moon vs. Mars (MvM) team was doing a comparative policy study, two students looking into the rationale for going to either the Moon or Mars. This included economic, political, and sociological implications. In essence, this was really two teams, although it started out as one. The team members split up due to personal differences and attempted the projects on their own. Our project was unable to establish contact with one half of the team, though we were able to maintain a working relationship with the team looking into the potential Mars mission.

Success of Each Team

Lunar Agriculture

First, the students researched various methods of technology related to agriculture. There was a division of labor among the three students to cover the problems of creating soil or doing without it, gas exchange and energy requirements; especially how to use solar energy underground if one was not going to use electricity to power grow lights.

The first issue that needed to be addressed was the energy source. Since solar energy is abundant on the lunar surface, that was the source of choice. However, the lack of atmosphere around the Moon allows radiation from the sun to penetrate deep into the surface of the Moon. This means that the lunar agriculture and habitat would need to be protected from cosmic radiation by tunneling underground. Various methods of controlling solar energy are available. These methods include: the conversion of solar energy to lasers which are sent into the habitat, then converted to electricity to provide power to grow lights, implement a bionic leaf, and bounce the light directly into the habitat through a system of mirrors. Depending on efficiency, cost, and feasibility any of these methods can be implemented combined with strategic placement of solar panels. The plant habitat created would need an artificial atmosphere to provide all of the essential nutrients. The plants should be located in their own section of the habitat, as they grow better in a warm predominantly carbon dioxide environment, whereas humans require a cooler more oxygen-intensive atmosphere.

The biggest problem for the proposition of lunar agriculture is the need for water and carbon. There is plenty of oxygen available on the Moon if it can be harvested from oxide rocks. The major question is whether you have enough energy, somehow hydrogen must be acquired. One option is to locate the base at the south pole of the Moon. There is the possibility that water in the form of ice is present which can be melted and used for hydration of both plant and human life. This would give one a start, but the source is not large enough to sustain a growing colony for long. Additionally, locating the base at the south pole allows for more consistent access to sunlight. At the equator, the Moon has 14 days of continuous sunlight, followed by 14 days of continuous night. The south pole has almost constant access to the light.

An alternative for finding water comes from the How High How Fast team. The HHHF group believes that they are capable of harvesting hydrogen in lower earth orbit, at least in the long term, though it will be difficult for them. More details of this will follow in the success section of the HHHF team.

The bionic leaf was a recurring technology that as first seemed like a viable option, but was soon discovered to be one of those technologies (like fusion) that seems to be “always be 50 years in the future”. However, using an alternative option provided by Paul Klinkman, the lunar agriculture group decided to formulate a method of agriculture of growing potatoes, yams, and other tubers underneath the lunar surface. Considering the extreme radiation given off by the sun that is present on the Moon's surface the team decided to work under layers of regolith as protection. In order to have light to promote photosynthesis, mirrors would be used to refract and reflect thin beams from the lunar surface to the underground fields.[3] They would then be spread out into full spectrum light.

NIAC

The NIAC team was a great success with a panel of 15 rather than 20 NIAC fellows. However, they compensated with a study of WPI students. They conducted a pilot test on the composite scenarios with mostly student data. In addition, they were the fourth wave in a series of groups trying to complete a multiple panel Delphi student on likely breakthroughs. There were existing expert and WPI Alumni Panels and about 15 cases gathered from NIAC fellows when they started their effort to get MBTI and evaluation data on two waves of surveys from each case. They were not able to meet their goal in terms of MBTI data from NIAC fellows, but added a current WPI student panel to the study so that they could make best use of the existing MBTI data gathered as part of our group dynamics study. In the end they ended up critiquing the breakthrough survey that they had used, which was designed by prior teams.

The NIAC team evolved their goals over time based on new information presented to them. In their words, "the data now exists to create a tool that could generate well grounded predictions" about future technologies. The NIAC team recommends this and that it should be based on what this team, the Drives team, the Fusion team, the Oxygen Harvesting and Agriculture teams had to say as they looked into one of the items on the survey in depth. The NASA Institute for Advanced Concepts is no longer being funded, so a new group of experts will need to be found if future iterations of this project are to be undertaken and if a next generation Delphi instrument is to be created.

How High How Fast

The How High How Fast team performed up to expectations by all markers. They were able to accomplish all of the goals that they set for themselves and were able to do so by all the allotted deadlines. Additionally, this team, along with the Lunar Agriculture team, was able to call a popular and convenient approach to the problem of forecasting the likelihood of a

[3] Lunar Agriculture paper reference

breakthrough in evaluating potential technologies into question. This team also did something innovative, though they were not themselves the inventors or innovators, they effectively assessed the technology.

The primary goal of the HHHF team was to determine if it was feasible to harvest gasses from the atmosphere for use as a propellant or otherwise. In reality, they went about analyzing the ideas of Paul Klinkman, who was proposing integrating many complex devices into one satellite system. The majority of those sub-systems have been proposed, designed, or used before- though not necessarily for this purpose. This includes everything from a massive thirty square meter scoop at the front of the craft, to the coolant system for the hot gases coming in at orbital velocities, to the tether that he proposed to re-boost the craft to counteract the massive drag without burning any of the gasses he was harvesting for fuel. The team had started out looking to reaffirm or refute a prior team's findings that you could not compensate with speed for the thinner atmosphere at high altitude in going about collecting gases. They made such significant progress that, with the single revelation that the atmosphere is layers of gasses and not a consistent mix, they were able to completely recast the question, ignore the approach of the other team, and back up Mr. Klinkman's claim that it is not only feasible, but may even be practical enough to be profitable to go into orbit and collect nitrogen and oxygen. The problem was the gathering of hydrogen way out in the outer layer of very diffuse gases 1000km from Earth. That was left an open question.

The data and research done completely refuted a prior team's conclusions that one would have to dive deep into the Earth's gravity well to collect gases ate levels where they were dense and then climb back into orbit. Specifically, by researching the makeup of the atmosphere at varying altitudes, they were able to find where their "sweet spots" of altitude would be for certain gasses. Originally they planned to figure out how fast they would need to be going in order to collect a reasonable amount of gas skimming the top of the atmosphere at 100 km altitude and then sort the gases. Now, they know they would be going between 17,000 and 18,000 mph to stay in orbit at 400 km, (just a bit higher than the I.S.S.) to be in an 80% oxygen zone. At 100 km, they would be getting 78% nitrogen and about 18% oxygen. The studies also show that a 50 kilometer electro-dynamic tether could in theory keep then at the desired velocity, despite the considerable drag they would encounter.

The team calculated roughly how much additional energy would be required to maintain a constant orbital velocity to counteract the drag placed upon them by collecting so much gas. It was determined that, although possible, it will be very difficult to supply the required amount of energy to this system. The energy needs for re-boost propulsion alone are large and they are trivial relative to how much power is required to cool the gasses down to liquid temperatures. The gas needs to be liquefied so that it can be easily separated and sold off. However, in space, solar energy is abundant and predictable, not intermittent due to clouds. With this in consideration the group planned to power the processing and gathering equipment with solar voltaics.

It is possible that this team raised questions of the validity of the analysis technique known as the Delphi method. The Delphi method previously discussed in the section about the NIAC and Drives teams. This is where a survey is presented to a panel of experts who are expected to make predictions regarding fields that they work close to. A previous years' panel had given a mixed reaction to the gas harvesting from the atmosphere idea. Of course, they were assessing the Deep Dive approach which was impractical at best. The question of how they would have reacted to Klinkman's approach is not clear. The old item, based on the proposal of the prior year's IQP, Harvesting the Atmosphere[4], was administered to both NIAC fellows and non-experts. Each panel that took the survey split on the subject, but, as with several other very speculative concepts, it received a low rating on average. Whether or not that approach was worth developing, the problem solved was based on a different question.

This year, it was found that because the question posed to the experts was misleading, the concept was not assessed in a reliable way. The fact that in the previous study they had been asked to evaluate a specific method of gathering gases instead of the concept of gas gathering really challenges the Delphi methodology, where specific techniques are key.

Often specific names of researchers are attached to the survey item as references. If the respondent is familiar with their previous work, this may result in bias either for or against the item that is not related to the actual technical feasibility of the item. On the other hand, having cited a source adds credibility. The gas harvesting item did not have such a reference. Additionally, if a small group of technically literate non-experts are able to come up with a proposed way to make it work with such a small investment of time and energy (approximately 9 man-months), it suggests that the approach is flawed. Experts may not be needed to do Delphi

[4] Andrew Port, John Scimone and Geoffrey Verbeke

forecasting if they are no more accurate than student teams looking into a possibility. There will always be a qualitative judgment aspect to rating panels, regardless of how well the question is posed. A bad item mis-focuses attention on the wrong issue and invalidates the whole approach.

All that being said, it should be evident that this does not suggest that there is no place for experts ever to be assembled; it merely suggests that a thorough investigation into proposals should be used in parallel with the gathering of expert opinions. Then the panelist can be given items that are not misleading or focused on the wrong technical challenges. The Delphi approach still requires those setting up the questions to do their homework. However, now a new breakthrough study could include a revised gas gathering concept and see how the experts in the field react to that compared to the other presented previously.

Space Station

The investigation into whether or not the ISS could ever pay for itself went very well according to the group's advisor. They worked well together and achieved their goals. This group was difficult to make contact with and as a result the details on the project remain unclear. While they worked well with each other, they never made any major attempts to reach out to the other groups. This is unfortunate considering how the ISS could potentially have been used as a test bed to see if the HHHF concept would work. While it could not be a depot for the HHHF group to deliver their gasses, it could be the place where the people overseeing an unmanned platform that spacecraft dock with to fuel stayed. Also, attempts have been made to grow crops on the station, the Lunar Agriculture group could have benefited from the knowledge that came along with those attempts. At the time of this writing, though, it remains uncertain as to exactly what conclusions were reached.

It is important to note that this project is a follow-up study to one conducted the prior year by Leonard Cohen, Shaun Comee, and Mark Ronge, who concluded that the ISS was too expensive to build and use as a space lab and would be unable to pay for itself over the long term in any capacity. They went further to say that the only possibility for this station to be commercially successful would be to build 20 large platforms each as capable as 10-20 current satellites worth of instruments and have the space station used as a mobile hub for repairs and maintenance of those 20 platforms. Man tending platforms would involve a visit to each about 1-2 times a year for refueling, repair and upgrade of instrument packages. 40 missions a year involving a week preparing, reaching, servicing, and returning from each platform twice would leave 12 weeks to maintain the space station itself.

New Space Initiative

The New Space Initiative Team based their project work on researching the technical and social implications of current space race between The Peoples Republic of China and the United States. It was supposed to be an update of a prior project but they ended up evaluating the future generation's perspective of NASA. The start of the research required the students to look into the social implications of returning to the Moon. First to start at a domestic level, the United States are known for their peoples extravagant drastic consumption habits. The world is currently running out of resources for energy and Americans take more than their share of and rarely make any effort to conserve. It may be possible for the Moon and space to hold an abundant source of some elements of energy that would eventually be able to replace our current forms of fossil fuel energy. This would not only provide the needed energy source but could possibly allow the prices for energy to decrease after an infrastructure is in place. The benefits that these new energy resources might bring will cause a demand to control them. Certain treaties have been put into place to avoid a war to control territory in space, but these agreements contain many loopholes, for example a country can give notice and withdraw from the treaty. Given enough time for a governing body to arrange things so it may be possible to "own" a celestial body.

The history of technical competition between the United States and the Soviet Union started at the end of World War II, when they began competing for the best jets, the best bombers, and the best missiles. The advancement of the missile technology eventually led to rocket and propulsion advances. The more Soviets were excelling, for example satellites and manned missions, the harder the United States worked to have the first man on the Moon. The many failed launch attempts by the United States to put up a satellite was an extreme embarrassment. This was to some extent self inflicted. The U.S. Army had a capable Redstone rocket built by Wehrner Von Braun's team of Germans. The U.S. Navy was given the green light to try to launch one using the all-American Vanguard Rocket, which was not ready and failed. After several failures of the Vanguard, the Army team received the approval to launch and succeeded on the first try. Valiantly on July 20, 1969, Neil Armstrong said the famous line "That's one small step for man, and one giant leap for mankind."

After the US Moon landing, the Soviet Union changed its' focus to spending as much time in space as possible in manned space stations. They were able to obtain invaluable information regarding the effects of prolonged time in space on the human body and doing various experiments with different types of technology like growing plants in their space stations. Several unmanned missions were also sent to gather samples from the Moons' regolith. When the Soviet Union collapsed and joined forces with the United States the information from their experiments and missions were available to NASA. Instead of constructing a MIR II, a generous contribution of the already built central hub module was given to the United States Space Freedom Project that was later named the International Space Station. Unfortunately, re-engineering the Freedom around the MIR II cost as much as it would have if built in the USA. In this case the symbolism was more important than the cost.

Now, as the Russians are allied with the United States and sharing information, they are also selling valuable information to the Chinese and helping the Chinese to jump start their space programs. The CSNA was not started from scratch. To start the main player in the creation of their program co-founded the Jet Propulsion Laboratory of NASA in the USA before paranoid U.S. Cold War politics forced him to return to China. More recently, the Chinese have access to Russian space technology ranging from the design of the Soyuz capsule to space suits and cosmonaut training. After being denied their request to join in on the International Space Station, China was forced to work by itself. However, this is not straying from the ideals of the Chinese. China strives to be independent and values the ability to thrive without help. There is no need for being dependant on foreign technology when pushing to go beyond it alone. It is no surprise that by the time of Bush's announcement of his support of NASA to return to the Moon as a stepping stone for Mars, China was already on their way without publicly announcing it. China officials declared that they planned on a Moon landing sometime as early as 2010, 10 years before NASA's estimated time of return. However, both nations want to build a semi-permanent base and 2018 is considered a more likely time of Chinese ability to do that. Even as China sent up manned missions, the United States still did not take serious action. However, as of January 11, 2007 Chinese with the anti-satellite weapons test, the United States has realized that new initiative must take place to keep its' title as the technological leader in this field. This action could either mean that China is testing its technology to start to move to be the next technological leader with its base on the Moon, or that a new arms race could ensue. The United

States has a department of space technology dedicated to military situations. This branch is known as the Air Force's Space Command. If China takes action to make near space an offensive territory NASA would not receive the funding and it would all go to Space Command to secure U.S. Military "assets" in space. This would not only be unfortunate considering the heightening of international tension but also because the Space Command stresses unmanned missions. Manned missions would be de-emphasized for the time being.

Chinese success in landing on the Moon would lead to drastic changes in the perceived balance of global power. As it stands now the United States is the technological leader not only in its' region but has few rivals in the world. Only the European Union and Japan come close to American economic impact, and they have not been interested in Manned Space. Russian, and now China, have been Military and space Rivals. Amidst the possibilities of what could be, China states that its space program is a peaceful organization, the mission of which is to:

> explore outer space, and enhance understanding of the Earth and the cosmos; to utilize outer space for peaceful purposes, promote human civilization and social progress, and benefit the whole of mankind; to meet the demands of economic construction, scientific and technological development, national security and social progress; and to raise the scientific quality of the Chinese people, protect China's national interests and rights, and build up the comprehensive national strength[5]

If China was to displace the U.S. as space technology leader, China would get considerable prestige and shine. They would be expected to surpass the United States in other fields as well. Once it is better organized and more innovative at advancing technology rapidly it could cause an economic change worldwide. China would become a force to reckon with and all the countries that have to turn to the United States for certain things, ranging from protection to high tech products will be able to turn elsewhere. This will drastically change their relationship with the U.S. even if they remain U.S. client states.

Other advantages arise when contemplating who has control over celestial bodies. As the natural resources of the world are being exhausted it is necessary to look for alternative sources friendlier to our environment. An example of an alternative energy source that is abundant on the Moon would be Helium-3. This raw energy source would be able to provide massive amounts of

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[5] White Paper

energy for a much lower price. In conjunction to investigating various forms of energy sources, technology to utilize these sources must develop as well. The natural vacuum environment of space would be the perfect situation to perform certain extreme experiments critical to developing fusion reactors. The space race could also have a very positive outcome of discovery of providing other new resources or new sources of important ones, but the cost of importing them should lead us to re-evaluate mass consumption as we know it.

During the space race with the Soviet Union, there was unwavering and strong support from the American population. This was most likely led by fear of what could happen if the Soviet Union emerged as technological leader, but even so, people were excited and mobilized by the technological advances and the challenge involved was not a war. Few lives were at risk and those that were, had volunteered. To have a space race with China the American public would need to take notice of what is really happening and recognize it as a potential threat. It is unlikely that the United States will react to China's reach for the Moon without the support of the American people. Currently, the American people do not think of the Moon as a valuable resource but rather a barren wasteland. Now the question here is: what if the American public could be informed that it has economic value and would that change the opinion? Would they then call for a new space race or say the U.S. should refuse to compete?

The NSI group found that the students, both high school and WPI were even les informed about space technology than expected. The two rounds of surveys and with information provided in between produced a dominant trend in increased support of a space race among the high school students. The team had predicted that students would first lean towards the space race and due to selective perception, stand by their initial views. Actually the first hypothesis was correct as there was majority in support for a Moon base. The information provided to the participants caused an enormous shift and the results became dominantly in favor of building a Moon base. The WPI students, who were initially thought likely to tend towards supporting a base and expecting a space race, were actually more pessimistic about the value of the Moon base. This may be because they have a better understanding of the technological and financial situations that a space race would entail or it may be the generation that was never excited about the Moon or told that the future lives in competition. Having started on career paths guided by that perception, they have more at stake and are more subject to selective perception. Thus, they are less likely to change their minds. Overall this study shows that education of the public is possible and necessary if the United States is to mobilize and take the actions of the CNSA seriously enough to enter the Moon race. Resistance of change is only natural to what is unknown or different. For there to be progress, progress must first be accepted. The support of the American public is needed if a new generation of space technology is to emerge rapidly. No one has yet made an adequate case for the Moon. Astonishingly was the success the NSI team made that case and swayed the opinion of the people who would be paying for the progress of the new space race in the future.

The NSI team struggled to complete their project. The initial plan was to have each of the three students go to Texas, Pennsylvania, and New Hampshire, their home states, during a break. There the students were supposed to recruit 3 science classes. However, only one student succeeded. The problem with the data that was collected from the one school in Pennsylvania was that the student failed to code the data so that he could tell who filled out each of the pre and post surveys. He was unable to track change at the individual level, while the distribution had clearly changed. A long slow processed was required to get the remaining students to collect data in two Worcester High Schools. In addition, it was very difficult getting the group to analyze the data obtained while some was still being collected. As a fall back plan data was collected in several WPI Social Science classes, but only one would allow a "post" survey. The only pre-Pennsylvania High School and pre-WPI data was a decent sample size. Analysis of the data began, and the time allotted to complete the project ran out. One student had successfully collected data and been the intellectual leader, then drifted away and didn't attend meetings. Another took over and got the WPI data in shape and wrote the report. The third "proved useless" as stated by the advisor. By then it was clear that the Worcester schools were going to produce data, but too late. A fourth teammate was recruited on a later schedule to complete the project. He collected the rest of the High School data and tried to do the analysis, but never clearly understood the theory behind it. The author leader returned to design questions to be answered and the advisor helped the final student figure out what tables were needed to answer them. The advisor also helped record some variables. Tables in hand, the student tried to write the final section but the lack of theory and expectation made it pure description, not theory testing. In the end, the author student returned again to edit and elaborate to write the discussion of results and conclusions so that the final paper would really do what they set out to do. It was a three person effort one person as the early inspiration to gather data and develop methods and instruments, the second taking on the role as taskmaster: coordinator and main author, and the third as data collector and main analyzer.

Fusion

The fusion projects were inconsistent in their communications with our team. However, their advisor stated that the two groups performed admirably after a slow start. They seemed to achieve their relatively modest goals to a high degree of satisfaction. Additionally, they each had a clear leader emerge from within their ranks, which allowed them to work well together and give each other, in the words of the advisor, "a high level of mutual support." They worked so well together, in fact, that when asked about conflict resolution, the advisor was forced to say that he had seen "very little, if any, conflict" between the group members in both teams. On top of that, the members put in a large time commitment to their respective projects, as well as really coming together towards the end of the project. The advisor had confidence that any future projects undertaken on these subjects would have a good foundation. The original rationale for the Fusion team was to resolve a dispute between the Helium-3 team of the prior year and the international cooperation or competition team. Helium-3 has no value without a breakthrough in fusion on Earth. Only one small team of the University of Wisconsin is working on Helium-3 and the leader of that group is valued by NASA but not the Department of Energy (DOE). The DOE is putting an extreme amount of funding into deuterium and tritium research.

The Helium-3 team concluded that once fusion in any form is mastered, people will want to use the most efficient fuel. He-3 will be useable soon after despite the higher energy, temperatures, and pressures necessary. Hence the energy crisis in 50-70 years will make He-3 valuable. The international cooperation team disagreed saying that the current policy is to do the easiest possible fusion and that will not require He-3 if and when it is available. The fuels present on Earth are abundant and the DOE policy is not cooperative with or trusting of NASA. He-3, according to the team, will be irrelevant to the energy program and the ITER project is at best going to produce a prototype ten to twenty years from now. This technology will be a major factor by 2050-2070 when oil reserves are depleted. He-3 will be worthless for the next two centuries until a lunar civilization looking for a local fusion energy source decides to take on the challenge of mastering the new materials. However, they will be basing their experiments on a foundation of a century of successful fusion of commercial fusion plants on earth. Earth will never need He-3 based on their readings.

The group that did more research into deuterium and tritium (the group that was communicated more with towards the end of their project) presented at the student Pugwash conference, allowing the group to see that they were very close to their final results but having difficulty simplifying what they had learned for a high school audience. The oral report was uneven, but those in the audience of proper background soon considered fusion to be a realistic source of energy in the near future. Their claims are backed up by the literature, with the Institute for Electrical and Electronics Engineers (IEEE) Power Engineering Society (PES) devoting an entire issue of their monthly magazine to the topic of fusion power last year.[6]

Due to the cheap and abundant source of energy that can be released by fusion, there is a strong economic incentive to invest in the technology. When the current state of fossil fuels is considered, the economic case for fusion gets even stronger, and the environmental improvement that changing to fusion would deliver has yet to be mentioned. If the world were supplied with an unlimited amount of electricity, at a reasonable cost, it would literally be the end of the majority of greenhouse gasses, both from power plants and from most transportation. Electric cars are currently in development that can achieve similar ranges to cars using a full tank of gas, and can recharge fully in as little as three and a half hours.

Obviously, there are huge implications for space exploration as well. Space colonies equipped with fusion generators would only need a small proportion of the fuel currently needed per year due to the massive yield per gram. Further, they would not need to worry about having access to the sun using large arrays of solar panels to collect energy. The best solar panels are only about 20% efficient and light is not very power intensive to start with. Plus, the panels are only effective when they are facing the sun. For a Moon base, for example, this means that a base with solar panels would have to either be space based (in orbit), located at one of the poles, or have to deal with 14 days of sunlight followed by 14 days of dark at the equator.[7] With a fusion generator the base could be continuously provided with electric power regardless of its location.

Finally, spacecraft equipped with fusion drives could be much faster than conventional chemical rockets. This is of great importance when dealing with human colonization of other

[6] November/December 2006, Vol 4, No. 6

[7] As we showed in the Lunar Agriculture section, there are advantages to a base located at the south pole of the Moon, but access to He-3 is not one of them.

planets. It has been shown that astronauts who are in space for extended periods of time begin to experience effects similar to osteoporosis, only at a much greater speed of deterioration. With the speeds that our shuttles are currently able to reach they would have to deal with the possibility of seriously injuring themselves once they emerged onto the surface of another planet after exposing their bodies to zero gravity for so long. This is not only inconvenient (and painful), but it is also potentially life-threatening considering there are no health services located anywhere on the planet of destination. Making the trip shorter by using a fusion drive is an easy choice for mission planners with access to the technology.

Given that the He-3 argument was not in the High School study and had been powerfully persuasive, the project initiative needed to find out if it was a viable argument. The argument would discuss whether a whole different rationale for a lunar-Earth trade system had to be developed. Possibly NASA had good reason for not talking about He-3 in justifying its' lunar base program and focusing on Mars. An assessment of the current Earth fusion program, when the first team to look into it got off to a slow and ragged start and seemed to falter, a second team was assembled and given the same mission, Ironically, they were expected to finish together, essentially merging. Only one report was submitted by some members of each team. The team that finished stayed narrowly focused on the breakthrough study item dealing with fusion energy. The team that didn't finish is trying to understand the broader picture in fusion technology and policy.

Drives

The Drives group evaluated the results of their surveys in term of averages. They compared their averages to that of the NIAC team results on the drives. They surveyed three types of people: general public, technically literate, and experts. The results for the solar sail were very similar for each group, the "skewness" and standard deviation followed suit varying very little. The significance and likelihood was rated lowest by the general public and highest by the technically literate. For the general public significance and likelihood had the most scattered responses which suggests a greater amount of disagreement. However, the general public rated this drive the earliest out of the other groups and had very little scattering. The technically literate group rated the solar sail the most likely and earliest out of all the drives. The data for their set was only moderately skewed with the distribution in the middle of the other two groups.

The experts rated this drive the least significant out of all the drives. Their data had low values for standard deviation on significance and likelihood, moderate values on timeframe and had the least spread data. Out of any drive data the expert significance data was the most negatively skewed out of any of the drive data and had the most skewing across all variables. The total averages of the solar rate this drive in between the Ion, highest, and nuclear, lowest at a time frame of "early" (present -2020). However, the results may be a little off considering the general public did not have responses for the ion drive.

For Nuclear drives the general public data had the highest standard deviations with the most scattered data for significance. They also had the lowest ratings of both significance and likelihood. Their timeframe was also rated extremely high. The nuclear drive was rated the lowest by the general public out of all the drives. If there had been data to for the ion drive it would have been easier to compare these results. The averages of the technically literate group were slightly above those of the general public and slightly below the experts. Overall the data was only a little dispersed in likelihood and was the most skewed, although they had the medium "skewness" for timeframe. The technically literate rated this drive the worst with the lowest ratings for significance, likelihood, and estimated the longest timeframe. The results from the experts on nuclear drives were the most concentrated with the lowest standard deviations. Out of all three the averages of the expert were the highest, however having rated the lowest of likelihoods. Results for the nuclear drive data had the most variations. Although this drive was rated the lowest overall the experts rated it higher than both the technically literate and general public. However, the timeframe for nuclear drives was the highest with the "middle" time frame (2020-2035).

The general public did not have a rating on this drive so their opinions could not be taken into account. The technically literate population surveys showed that later timeframe than the experts. The Experts likelihood contained the most scattered results, although most of the standard deviations were around one and their significance the most concentrated. The experts rated this drive the most likely, significant and earliest among all of the drives. The timeframe for the ion drives was skewed in both directions, but the averages for the three variables occurred within a 5% of the mean value. Ion drives were rated the highest out of all the drives. The highest by the Experts followed by the technically literate.

Moon vs. Mars

Unfortunately, this team was not as successful as the others. The Moon vs. Mars project quickly deteriorated into two separate individual projects working on related issues never brought together. As was stated in the section regarding the team missions, one of these teams continued to cooperate with the OCM team when it came to our requests for progress reports and additional information. The other stonewalled and ignored attempts in communication. That story was lost to the project ether but was probably the least successful individual effort. The project making and assessing the case for the Moon as a policy project focus was the one that was the one that the OCM team never really managed to establish contact with. In effect, this responsibility became part of the OCM team.

The project student looking into the case for Mars exploration was forthcoming about the progress of the project, but it was ultimately considered to have come out very poorly for lack of internal comparison. The team started out as a two person group, but the two were unable to work together. Ultimately, the case for Mars boiled down to, "well, we should go because it is cool. It is another planet; we have not been there before, so let us find out what we can find there." It was readily admitted that this was not as comprehensive of a project as it could have been. As a result, this is one of the projects the OCM team would like to see attempted again next year. The lack of contact with the Mars Homestead Team and 4-Frontiers Group seems to be a grievous oversight.

One issue that may have contributed to the splitting of the team, could be the process a project follows to be advised. In most of the space technology and policy projects, Professor Wilkes will post and describe a possible project that will hopefully attract students. From there faculty members meet and decide who is interested in advising the project. In the case of Lunar Development and Moon/Mars and Can the Space Station Ever Pay for Itself, the advisor that chose to lead the teams decided to work independently of the other space technology and policy teams. In some cases advisors will interpret the summary of the posted project differently than intended and could potentially change the goal of a project entirely. The whole project gets redefined and in the case of Lunar Development, trivialized and in the case of Moon and Mars the students were not given a starting point that is based on continuing monitoring of the policy debate. The involvement of the professor that had initially posted the project, or the availability of constant contact with the lead advisor, the projects would have succeeded in the manner expected. This option is considered because the teams fell apart for lack of the project rationale and starting resources being adequately conveyed.

In effect, the position emerging at MIT is that the barrier to colonization are lower on Mars than the Moon, and since the goal is a space colony the outlook is to do it as a one way trip. The position of WPI is that interplanetary trade will be needed to justify and pay for space exploration. The Moon is a very interesting space environment close to Earth and complimentary to it. The case for economic exchange can be made in the form of Helium-3, among other things. It is like crossing the Mediterranean Sea to build a colony in North Africa on the edge of the Sahara Dessert instead of crossing the North Atlantic to reach the new world.

Mars has nothing Earth needs. There is no chance that this effort will pay for itself. Therefore, building a colony there has to be an end in itself, rather than a means to one. Space enthusiasts will tell you that the goal is longer and trumps economics. Indeed the tale of the human race is all hanging in one place, planet Earth. We should double the chances of survival as soon as possible with a colony elsewhere. This is not a matter of dollars and cents, but a cultural and species imperative. The question remains, how will this be paid for? Defending the Earth against an asteroid or comet is probably easier than building a city on Mars that is self sustaining. Planetary defense doesn't require manned technology and thus costs 5% as much as manned systems.

The NASA mindset is so biased toward manned technology that it has been slow to address the need to monitor NEOs threatening. Indeed, it refused money offered by Congress for that purpose and SpaceComm will probably take the responsibility. Meanwhile, the Europeans are taking the lead on space watch and the Russians are thinking about asteroid deflection systems. NASA is saying the Earth is probably not defendable, but the human race and civilization can be restarted on Earth after a catastrophe if there are surviving colonies safely established and self-sustaining elsewhere. Mars would be the easiest place to set up a colony, and science done there might help people understand what the future fate of the Earth will be. Mars at one time had an ocean and a thick atmosphere, but lost them. We really want to know how that happened and if the process can be reversed. The Earth will ultimately be consumed by the Sun so the sooner humans learn to live elsewhere the better.

It is a plain fact that humanity is going to both the Moon and Mars (with NASA heading for the Moon as a place to practice for Mars, and the majority of the international space programs aiming towards the Moon), but the case for both systematically compared remains to be seen. Although this project attempts to state the case for the Moon based on the larger issued addressed, the connections between the other projects we are surveying, it was not possible to cover the whole literature, or even the 21 projects done prior to completing this year. The case for Mars has only been presented to the WPI community in the form of a brief presentation made by Mr. Palaia during the Student Pugwash conference. There is a Mars movement that is very influential at the Massachusetts Institute of Technology (MIT), where a Mars Homesteading project exists. It should be evident that the lack of a policy evaluation challenging the conventional wisdom of NASA that the Moon is not interesting and putting that the context of the current Mars focus is a problem that should be rectified in future year's projects. There can't be so much of a focus on the Moon that there isn't a look into the Mars question that is shaping the U.S. policy towards space.

Correlation of MBTI Data with Team Success

The Myers-Briggs Type Indicator is a questionnaire method of identifying person's personality. It is based on Jungian Theory. The group dynamics theory behind this project is that specific combinations of personalities are complementary to each other, allowing some team makeup's to be more likely to excel at innovation. Other cognitive mixes would reduce the odds of success in a team called upon to innovate. One of the primary means by which we determined the level of success of a team was to ask the team members themselves about their perception of group process and success. This was done by using a survey which can be found in the appendix. For teams that responded to the survey, this was the primary descriptor of success. For teams who did not respond, the OCM team out forth a great deal of effort to contact the advisor to the project and get their impression of how well the project had gone via an interview.

Many times in the following sections there will be a description followed by a numerical value in parenthesis. This numerical value is given in the form of (response given/highest extreme). The response given is on a scale of one being the least extreme, to the most extreme, which is either a four of five depending on the question being asked. For example, in the question asking about how closely the advisor worked with the group, it was on a scale of one, where the advisor was there to frame the project objective and grade the outcome, to four, where the advisor essentially acted like a full member in the group. This contrasts with the question on the survey related to the amount of new knowledge required for the project, ranging from one, where all necessary information was either already known or easily accessed, to five, where the group found some new information that was not previously available in the literature. If they queried experts on the topic, that was also going beyond the literature. It didn't have to be a new discovery by the students.

For the teams which did not respond, when we contacted the advisor we offered an abridged version of the survey we sent to the teams. This was left open ended, it was less important to that there was full and complete records than that the group received roughly comparable responses and wanted to ensure that this was as convenient for the advisors as possible. This does leave a little more up to interpretation when it comes to the advisors comments, putting them together with the documented observations. However, in most cases there was a sufficient amount of information to make accurate judgments on the outcome of the projects to report those results here.

In order to fully understand the analysis technique, an explanation of the MBTI personality indicator is required at this point. The following quote was taken from http://en.wikipedia.org/wiki/Myers-Briggs_Type_Indicator on March 3, 2007. It describes the various preferences that can be attributed to a specific person based on this half hour questionnaire. For the remainder of the paper, the words introvert, extravert, intuitive, sensing, thinking, feeling, judging, and perceiving are defined as in the quote.

> The terms Introvert and Extravert are sometimes referred to as attitudes. An introvert is more interested in the inner world of ideas; an extravert prefers the outer world of people and things.
>
> Sensing and Intuition are the perceiving functions. Jung called them the irrational functions (as a technical term, not as a pejorative), as a person does not necessarily have control over receiving data, but only how to process it once they have it. Sensing people tend to focus on the present and on concrete information gained from their senses. Sensing prefers to receive data primarily from the five senses. Intuitives tend to focus on the future, with a view toward patterns and possibilities. These people prefer to receive data from the subconscious, or seeing relationships via insights.

Thinking and Feeling are the decision making (judging) calculus functions. They both strive to make rational choices, using the data received from their perceiving functions, above. Thinking people tend to base their decisions on logic "true or false, if-then" connections and on objective analysis of cause and effect. Feeling people tend to base their decisions primarily on values and on subjective evaluation of person centered concerns. Feelings use "more or less, better-worse" evaluations. It could be said that thinkers decide with their heads, while feelers decide with their hearts. When Thinking or Feeling is extraverted, decisions tend to rely on external sources and the generally accepted rules and procedures. When introverted, Thinking and Feeling decisions tend to be subjective, relying on internally generated ideas for logical organization and evaluation.

Judging and Perceiving refer to the S/N and T/F dichotomies just described. J or P records which of the two dichotomies is used for dealing with the external world. J types tend to like a planned and organized approach to life and prefer to have things settled. P types tend to like a flexible and spontaneous approach to life and prefer to keep their options open. (The terminology may be misleading for some—the term "Judging" does not necessarily imply "judgmental", and "Perceiving" does not necessarily imply "perceptive" in the usual sense of the word.)

In J-types, the preferred judging function (T or F) is extraverted (displayed in the outer world). J-types tend to prefer a step-by-step (left brain: parts to whole) approach to life, relying on external rules and procedures, and preferring quick closure. The preferred perceiving function (S or N) is introverted. On the other hand, in P-types the preferred perceiving function is extraverted, and the preferred judging function is introverted. This can result in a more spontaneous approach to life (right brain: whole to parts), relying on subjective judgments, and a desire to leave all options open.

Introverts turn their dominant function inward, so the J or P indicates their auxiliary function. In INTP, for example, the P says that the perceptive function, in this case N, is the individual's extraverted function, so to most observers, the individual appears to be an iNtuitive; the INTP's dominant function is the T, but it is introverted, and thus harder for others to observe.

Lunar Agriculture

The Lunar Agriculture group was made up of I?TJ, ISTP, and INTP members. The I?TJ is given an inconclusive score for intuitive vs. sensing, though they technically had a score of S3. In MBTI theory, a score of five or less is inconclusive and so the score will be disregarded. The OCM team received two survey responses from them, from the ISTJ and ISTP members. Their responses were surprisingly similar in almost all respects, except for how they envisioned their roles. Their results regarding the roles are documented in the following two tables:

	Visionary	Catalyst	Stabilizer	Troubleshooter
ISTJ (self-image)	X			
ISTP		X		
INTP			X	

	Visionary	Catalyst	Stabilizer	Troubleshooter
ISTJ			X	
ISTP (self-image)		X		
INTP				X

Interestingly, each member thought of the fit they provided as a “reasonably good” fit, or a two on a scale of four, with one being a “very good” fit. None of the members were friends prior to the project. Neither person who responded believed that a leader emerged or was chosen from the group. They also agreed that the advisor worked closely with the group, but left all major group decisions to the group members themselves. Neither of the respondents considered the project to require a significant amount of new knowledge, as all new information could either be found in the literature or in discussions with non-experts. The two team members both agreed that they were optimistic in terms of how well the group got along in terms of team work, and they both thought the final report would come out well. On a scale of one to five with one being good, they agreed that the overall success of the project would be a two. They also agreed that their level of cooperation was adequate, rating it as a three.

The remainder of the specific questions had them rating their success as one different from the other respondent. When asked about how well they accomplished their specific goals, the ISTJ respondent thought that they did very well, rating their success as a one, and the ISTP thought they deserved a two. In terms of both conflict avoidance and resolution, the ISTP rated the team as a four, and the ISTJ rated them as a five. Similarly, the ISTP thought they deserved a three in terms of intragroup communication, while the ISTJ believed they should receive a four. On the other hand, when it came to the division of labor, the ISTP thought they did better than the ISTJ thought they did, with respective scores of five and four. The final question on the survey had the two respondents agreeing with each other once again, saying that another project of similar difficulty would result in another project of roughly the same quality as this one. As a side note, the ISTJ respondent claimed to have put in approximately ten hours of work per week on the project, while the ISTP was responsible for five hours per week. Each of them thought they did “a sufficient amount” of work in terms of time spent per week, and effort per task. This was related to a score of three out of five. The problem in this case is that the missing survey is from a key member of the team. This member was considered by his partners to be the stabilizer/troubleshooter and by the advisor the visionary and was the intellectual leader of the team. This member best understood the larger purpose and significance of what the project was, making him the best presenter. It is unsure how this member viewed his role. However, it is known that the SJ and NP balance in the team worked. This was a successful team in part because of the social skills of the INTP who was balancing the ISTJ. Over all the ISTP saw it clearly, ISTJ was the stabilizer, and the INTP the troubleshooter.

NIAC

The NIAC team was made of three members, each having a different cognitive style. There was an ENTP, an I?TJ, and an INFJ. The NIAC team is the only group that the OCM team received full feedback from on the survey. Each of their three members provided responses, which gives the best feel for how the group actually performed. However, with all the responses having somewhat disparate responses contributes to the confusion about how the project actually went. It is known that the project overall went well, but who performed what roles is something hard to determine. The best data to support this is a self perception supported by one other team member.

As before, the team members each thought the breakdown of roles was different, as shown below:

	Visionary	Catalyst	Stabilizer	Troubleshooter
INFJ (self-image)				X
ENTP	X			
ISTJ		X		

	Visionary	Catalyst	Stabilizer	Troubleshooter
INFJ		X		
ENTP (self-image)	X			X
ISTJ			X	

	Visionary	Catalyst	Stabilizer	Troubleshooter
INFJ	X			
ENTP		X		X
ISTJ (self-image)			X	

There was, again, little agreement. The ENTP and ISTJ agreed that the ENTP was a troubleshooter, and that the ISTJ was a stabilizer, while the INFJ and ENTP agreed that the ENTP was a visionary. None of them knew who the catalyst was, though, with each of them disagreeing entirely. Given the fact that the ENTP agreed with both the INFJ and ISTJ on at least one item, it seems that the ENTP might have the most accurate assessment of the team. It is best not to assume one person right and the other wrong, but view all as providing subjective data. While the INFJ thought that the fit was "very good," (1/4) each of the other two believed the fit to be "reasonably good" (2/4). This seems to lend more weight to the theory that the agreement was pure fluke, as the ENTP was not as confident as the INFJ about how close of a match the descriptions were with the group members, despite being in closer agreement with the other respondents.

In regards to leaders in the group, the INFJ was the only one who did not believe that a leader existed in the group. The ENTP and ISTJ each believed that a leader emerged from within the group, meaning that one was never officially chosen, he just happened to step up when necessary. Similarly, the INFJ differed from the other two in terms of how much input the advisor of the project had, giving him more credit than the other two, as well as how much new knowledge was required for the project, saying more was necessary. The INFJ thought the advisor worked closely with the group and was involved with all major decisions (3/4), whereas the ENTP and ISTJ thought the advisor worked with them, but did not micromanage the project, and primarily let the students handle things themselves (2/4). Regarding new knowledge, the INFJ thought they needed some help and guidance from local experts and the advisor (3/5), while the ENTP and ISTJ thought that only a little new knowledge was necessary, and that it could be found in literature searches or discussions with others (2/5).

When it came down to rating how well the project went, though, the three team members were in agreement that, overall, the project progressed very well (5/5). The INFJ and ENTP thought that they had done a good job (4/5) of accomplishing their goals, while the ISTJ believed they had done a very good job (5/5). In terms of cooperation between the team members, the INFJ and ISTJ thought they had done a “good” (4/5) job, while the ENTP rated them as giving a “very good” (5/5) performance. In reference to avoiding conflicts, the INFJ and ISTJ agreed they’d done a “good” (4/5) job, while the ENTP graded them perfectly, saying they deserved a “very good” (5/5) rating. The most widespread of their responses was related to how well the group resolved conflicts that did inevitably arise. The INFJ thought that the group had done “adequately” (3/5), the ENTP thought they’d done a "good" (4/5) job, and the ISTJ thought they had done a "very good" (5/5) job. For the division of labor question, the ENTP was slightly less enthusiastic than the other two, saying that they had done “adequately” (3/5), while the other two believed they had done a “good” (4/5) job. Finally, regarding group communication, the ISTJ was very happy with how things had gone, rating the team as “very good” (5/5), while the INFJ and ENTP thought they deserved a rating of “good” (4/5).

Regarding personal commitment to the group, the INFJ thought that they had put in an “incredible amount” of work (5/5) while applying a “sufficient amount” (3/5) of energy per hour to the task. The other two team members each rated themselves as putting in a “sufficient amount” of both time and energy (3/5). Interestingly, when asked numerically how much time they had put in, the INFJ did not respond at all, the ENTP said an average of approximately 13 hours per week, while the ISTJ only put in 2.5 hours per week. This data alone gives rise to questions about the validity of asking someone qualitatively how much work they had done, when each of the respondents said they had done a sufficient amount of work, but one had done more than five times the work as the other. Also, it calls into question whether or not the INFJ really did an incredible amount of work.

The section of the survey relating to when the team did the best on a per term basis may have been misunderstood by some of the team members. While we asked for a progression over time, only the ISTJ responded in the way we had intended for them to. The INFJ and ENTP merely indicated when they had done the best. Unfortunately, even given this, the team members were not in great agreement. Regarding when the group was most focused, the ISTJ and ENTP thought they did best in the third term, while the INFJ believed they did better in the second term. When asked when there were the fewest major conflicts the team was in complete agreement. Apparently, the first term was a great time to get to know each other and begin work, although it went downhill from there. The ISTJ believed that as time went on, the second term was not quite as good as the first, and the third not as good as the second. When asked when the group was best at resolving conflicts, the ENTP and INFJ members thought that the third term was the best, despite (or possibly because of) having the most conflicts. The ISTJ thought that the team was fairly consistent throughout the year with regards to conflict resolution. In terms of division of labor, the results were the same as with conflict resolution, with the ENTP and INFJ team members thinking the third term was the best and the ISTJ thinking that they did equally well throughout the year. There was a slight shift when the team members were asked about communication within the group. The INFJ and ISTJ members responded that the group was consistent throughout the year, while the ENTP thought that they had really come together at the end of the year. The last two "over time" questions had the group members agreeing fairly well with each other. The ENTP member thought that they had spent the most amount of time, as well as the most amount of effort per hour, in the third term, which the ISTJ member supporting by saying that as the year had gone on, more and more time and effort had been put into the project. The INFJ member did not contradict this by saying that another term had been more intensive, but instead they believed that they had been fairly constant over the course of the project.

The final question on the survey, which asked about how well the group would expect to do should they undertake another project of similar difficulty, had only two responses. The INFJ member did not respond for some reason, but each of the other two members believed that they would do better on a future mission. A possible reason for the omitted response would be that this member would not want to work with the same members again, and felt excluded over time.

How High How Fast

The HHHF team was very successful, but for some reason did not want to communicate with the OCM team as to how they felt that they performed. The team was made up of an ISTJ, a IST? with an J1 rating, and an ISTP. Additionally, they worked very closely with their co-advisor, Paul Klinkman, with a psychological type of INTJ. Mr. Klinkman acted as a sort of buffer between the student team members and the official advisor, Prof. Wilkes, who is an ENTP. Mr. Klinkman and Prof. Wilkes are both described as intuitive and thinking. Mr. Klinkman and the student members have a striking similarity of preference. Given that none of the team members chose to fill out the survey we administered, there is an attempt to fill in the information as best way possible. In this case one can draw upon observations made of the group over the course of the project. As was reported in the "Success of Each Team" section, the HHHF team was very successful in assessing the technology it set out to investigate. Although the OCM team is unable to place the participants into roles, this is attributed the fact that the group seemed to get along very well to their being friends from the outset of the project, and being very similar personalities, all I, S, and T. This seems like it really helped them to work through the project, as they each knew how the others thought, and communicated well. Perhaps, they had worked with each other on prior projects as well. At this point making a conclusive judgment as to who the leader in the group was (although the IST? clearly became the spokesman for the group), or even if there was a leader in the group is unclear. Certainly, it seemed to be more of a collaborative effort than one of command and obey, but this is an outsider's perspective. From observations of how the group acted with their professor it was clear that although he guided the effort, he was by no means overly controlling of the details. They were subject to debate with Mr. Klinkman via e-mail and weekly meetings.

The team definitely needed some amount of new knowledge, but the group was made from three mechanical engineering students, so they might have been better prepared for this project than someone of a different technical background. However, given the complexity and sheer number of systems in play for this project, it would be impossible to expect three junior year undergraduate students to have the full range of knowledge needed for this. Based entirely off of outside observations, this group seemed to accomplish its' major goals, staying well focused on getting things done as they came up. No major conflicts were noted, and due to the fact that it was never made into an issue while any of our group was present. In relation of cognitive types, the final assessment is that there was no prominent visionary, the stabilizer/troubleshooter is the ISTJ1, the catalyst the ISTJ, and the ISTP had no role until the end then filled a gap working closely with the ENTP visionary advisor.

According to Professor Wilkes, the team devolved into a two person effort until the end. There seemed to have been no real problem arising for the two who could attend the meetings. The third member was carried by the other two for majority of the time.

Space Station

The space station group did not participate in this study. There is no hard information on them in regards to either survey responses or MBTI data. They were working under an advisor who, according to outside sources, does not believe the MBTI is useful, and so had no incentive to complete either the MBTI test or the post-project survey. As reported in the "Success of Each Team" section, however, the advisor was very happy with the progress the team made. Overall, he rated them as "very good," in performance with little need for conflict resolution. This report was never viewed, therefore the quality and originality is unable to be assessed.

New Space Initiative

The New Space Initiative Group was initially made up of three members for their first term, with an additional team member added in at the start of the second term of the project. The original members had MBTI scores of INTJ, EST? (J1), and INFP. The "new" member of the team was an ISTJ. The initial group leader was the ESTJ, who led them to focus on the survey idea. That person also developed the survey in cooperation with the INTJ, who really wanted this to be only part of the project. The INFP waited until they were told to do something, took no initiative, and contributed relatively little. This person was mostly a support person and effectively a free-rider.

The first test of the group was data collection. Each group member went home for vacation determined to administer the survey, give a presentation and a post-survey in their old high schools. The ESTJ did just that in three classes of about 30 students each in rural Pennsylvania. The other project partners returned empty handed. Arrangements were made to collect data in Worcester and analyze the data in hand. None of the members wanted to do the analysis, at least until the data set was complete. However, additional data was collected at WPI while efforts were made to collect more data in Worcester High Schools. Hypotheses were developed, and the Pennsylvania-WPI data were crudely compared.

The INTJ took over the report writing the hypothesis development effort. The INFP wrote one section and disengaged. The ISTJ partner created the data set, learned to use the statistical analysis tool SPSS, collected the additional data in Worcester at Doherty and North High, and started analysis on the data. He then delivered the tables to the INTJ. The ISTJ did not really understand the theory, but did what the INTJ partner and ENTP advisor asked for, so long as the request was specific and the logic was clearly explained. In the end, the ISTJ wound up doing a good analysis and writing up a first and second draft of it. The INTJ wrote the final draft. Our conclusion is that the "real" team was made from an ESTJ, INTJ, and ISTJ. The ESTJ did a preliminary analysis and enough to turn it in and graduate. The bulk of the project execution and reporting was done by the INTJ and ISTJ, the former running late and going overtime so as to not abandon the new partner.

Fusion

The Fusion team was made of three members, an INTJ, ISTJ, and ESF? (J1). Purely by coincidence, this group had both the most and least extreme personalities contained within it out of all of the students for whom we have data. The ESFJ had scores of E9, S7, F19, J1. Considering the low score of three of the four dimensions, there is a possibility that they could be wrong. This could mean that the data is unreliable. The ISTJ, on the other hand, had scores of I41, S41, T57, J39. It is interesting to note that within this group the ESFJ was the leader and organizer of the group, contributing most of the intellectual leadership to the project. The ISTJ was clearly the least creative member of the team (though he did contribute to the overall productivity of the group). This may lead one to believe that a person with a more moderate personality might be a better leader. However, this conclusion is tempered by the fact that the INTJ had scores of I41, N9, T33, J39. The INTJ team member, according to their advisor acted as a sort of deputy leader, focusing primarily on quality control. To show some comparative values the "average average" was roughly 26.3 and the median average value was 26. The overall analysis of the Fusion teams' cognitive types would be that there was an intellectual leader, taskmaster and a productive support member. The data collected is not actually a composite based on a groups' consensus using the best rationale. However, it is clear that all members were involved and ended up mastering the material enough to render an opinion and justify it.

Drives

The Drives group consisted of an INTJ (I33, N15, T9, J37) and an INTP (I51, N51, T57, P9) with 3 out of 4 reliable dimensions for both. The two members had very similar personalities, with only the variance of the final dimension, and as a result were able to work well together. They did not respond to the survey we administered, therefore most of the judgments are coming straight from interviewing their advisor with some supporting evidence coming as a result of observations over the course of the project. Both of those pieces of data are in support of the group having worked well together. The advisor thought that the two of them could have used an additional team member (in his words, they "suffered from a lack of manpower." It should be noted that when asked questions "relative to other groups you've advised," this advisor was complimentary of all three groups he had worked with on topics related to space technology and policy (the Drives and the two Fusion groups). In fact, he used the same language to describe each of them, sending one blanket response for all three. This is not to take away from any of these groups, we comment merely to fully make the reader aware of the facts. These teams ended up working together in parallel and blending.

The INTJ member of the group was the leader among them, but the similarity between the two personalities makes it difficult to say that there was more of a leader, both contributed. The two team members worked well together, as would be expected from their similar personalities, and their working relationship only seemed to get better as time went on. The advisor believes, and the OCM team agrees, that the Drives group would perform even better if they were to attempt another project together.

Moon vs. Mars

The Mars portion of this team was comprised of only one member, as was stated previously. Unfortunately, there is no data pertaining to the personality type of the Moon member, who dropped out, but the Mars member was an INTP. The responses to the survey follow, although some modifications to the original answers have been made based upon comments added. Where this has happened, both the original response and the interpreted response are provided.

When asked to categorize himself in the group, the final group member considered himself to be very much a visionary and troubleshooter, and not at all a stabilizer (which, according to MBTI theory, fits). Regarding how good a fit the above characterization is, it was answered that due to the fact that the member was not truly in a group after the first term, no roles developed. However, given the fact that they were only responding about their own role, it is felt that this would count as a very good fit.

Predictably, the two initial members were not friends with their former partner, and although the final member said that no leader was present in the group, the decisions made in regards to the project were theirs, and not their advisor's (1/4). Of course, it was stated that the project turned out poorly, both in regards to team work and the written report. It is possible that this comment is based on the fact that they were forced to take the lead in the project and did an inadequate job of managing the responsibility. They did need a little (2/5) new information for his project, and added that they attempted to change this from a pure research project to a feasibility study. The overall result, as commented, turned out "poorly" (2/5), which was the same as when the member was asked about both how well they had accomplished their goals and how well the team had cooperated on getting tasks done. It is possible that they needed more active advising to get started. Regarding conflict avoidance, they rated themselves as a one out of five, saying that the major conflict that arose in the project was over participation in meetings and resulted in the dissolution of the team since the original member was not willing to be tied to an unresponsive partner. The conflict resolution for the project was very good (5/5), because once the team had broken up there was no further need to resolve conflicts at all. Of course, the fact that the team dissolved nullified the questions regarding division of labor and communication within the group. When it came to putting time and effort in the project, the member did not feel that they had done a satisfactory job, saying that they had only put a little bit of time in per week, and the amount of effort required was only a little as well (2/5 for each).

When it came to tracking how the project had progressed over time, there did not seem to be any major trends regarding improvement or deterioration. The final member thought that while they were the most focused and spent the most amount of time on the project in the first term, they spent more energy per task in the second. Also, the best term for resolving conflicts was the second term, when the group broke up. Obviously, the fewest conflicts occurred in the third term, and the final member felt that intragroup communication was fairly constant (in their words, it was never any good). Also contributing to the poor outcome was their lack of time commitment, averaging between two and three hours per week. This is due, the OCM team believes, to the fact that the final member was concurrently undertaking their MQP and was likely spending a very large percentage of their time working on that project.

Although it was claimed that a second project with the same teammate would come out worse than this one, as would a second project undertaken alone, it seems like this is merely an expression of their frustration with the project as a whole. Given their other responses, it seems unlikely that a project would come out any worse than the current one. It should be realized, however, that the member was very candid with their responses, and he may legitimately believe that it would come out worse. Unfortunately, the cognitive type of the lost partner is unknown. The final member seemed to want an organized taskmaster partner who would take responsibility.

Self-Evaluation

As should be evident from the title of this section, the OCM team is about to move into a discussion of how well it performed in regards to the various goals set, a sort of self-evaluation. Each of the goals is evaluated individually, as has been the convention from the beginning of this paper.

Communication

When the OCM group first started action, it was already the second term for most of the other teams that the group was to be working with. Very few of them had much, if any, previous contact with the other groups. The one exception was that one member of the Lunar Agriculture team had originally wanted to be a member of the HHHF team because that was where his friends were working. He initially tried to act as a liaison between the two groups, however was quickly immersed solely in the progress of his own project. For the purposes of the OCM team, as well as the progress of the teams, this overall lack of intra-communication was unfortunate and rectifying the situation became an immediate goal.

Throughout the first term and well into the second, as mentioned previously, weekly meetings were held with the all teams. To establish an infrastructure for communication one team member from each group was designated to be the in-house communicator and another to be the common link with the advisor. This enabled each of them to get in contact with each other more easily. Having one point of contact is always more efficient when dealing with an outside organization, as one does not have to worry about sending the email out to the appropriate party, the point of contact is already known.

This list of representatives was made available to the groups by both supplying a physical copy of it to those present at the meetings and by placing it on the web for easy access. For situations when one of our members, our advisor, or any other person wanted to contact the as a whole the people involved in the space technology and policy projects, an email alias as created with all necessary parties included. The alias was often used to send out notices about upcoming meetings, events, or other miscellaneous advisories to the groups. The alias was used for intra-communication in a few instances including when the NIAC team needed the students to fill out their survey they were able to easily get in touch with each of them to let them know where the survey was online. When the number of responses was found to be insufficient, it was used to encourage more people to participate. When it turned out that even this did not work, the OCM team wound up semi-coercing many of the students into taking the survey directly following one of the weekly meetings. The OCM group also used the list to send the final survey at the end of the project as well.

Aside from meeting notices and requests for survey responses, the alias was often used to send out links to NASA news, space related newspaper articles, and other internet-viewable information. Unfortunately, due to the number of times this capability was used, it seemed like many people started to ignore the emails sent out. One recommendation would be that, for future multi-group projects, set up two separate email lists: a reserved alias for strictly project-related emails, and another optional list for those who want news of the space technology and policy world. This would help to ensure that people receive all the emails that they need to and none of those that they do not. Hopefully this would prevent everything that comes in from the alias being regarded as spam.

Presentation times were assigned to each group to relay project information. Also encouraged was discussion between teams that could have overlapping objectives. Having projects relate their ideas and possibly involve each others theories in their own was a main reason for our trying to instigate discussion. These discussions were coerced by having the OCM members create groups of teams and then make a list of conversation topics to stimulate discussions. The lists were then divided between the OCM members and our advisor. Moving from point to point these topics were created to show the members of the various teams that project issues, theories, and information could overlap. Topics were specifically noted where one groups research would be needed or benefit another. For example, there was an effort to incorporate the International Space Station as part of the How High How Fast project as a possible trading station. However, the OCM had no real authority over group direction and the advisors were rarely present. Therefore, the group could only supply possible suggestions for group objective shifts. The attempts prevailed as mentioned in the Goals and Methods section entitled Communication, noted were the best examples of intercommunication between the HHHF team with the Lunar Agriculture team and Lunar Development team with the Lunar Agriculture team.

Due to scheduling constraints, the meetings in the second term were chosen to prepare for the IASTS conference in Baltimore. Classes started during the second week of January and the conference was held the first weekend of February. This would not leave much time for those groups that were presenting to prepare. The focus on the conference essentially made the groups that were not participating in Baltimore serve as an audience at these meetings. For several meetings in a row, the non-Baltimore teams were not were not learning or discussing anything new, but rather passively watching other groups who were presenting. This made it impossible to persuade those groups to continue attending the meetings.

After the IASTS conference, it was difficult to pick up again where the team had left off with supporting intra-communication. At this point there were only a few weeks till the end of the term and the majority of the groups were working to finish their reports. Most groups did not expect (or want) to hear anything that would alter what it was that they were writing at the time, bringing to a close the efforts to transfer relevant information between them.

The attempts to unify perspective and transfer ideas between groups were fruitful. The OCM group members sat in on meetings and became middlemen for the transfer of information. Most of the information asked for by the other groups was NIAC survey information to see if their own research supported the expert assessment. Still, it was apparent that a connection between teams was established. A means by which members of the teams could contact other teams to discuss ideas and information comfortably had been created. The success in achieving this goal will hopefully encourage the future OCM groups to establish a similar connection. With increased communication between students involved with projects in regard to future technologies, the possibilities of cross fertilized ideas and concepts that are built on one another are much more likely to emerge. Then, the whole is more than the sum of the parts.

Overview of the Results

There was moderate success with forming a plan for action. Due to the number of projects that were difficult to get information from, either because they were unsuccessful or incommunicative, it is difficult to make sure-fire assessments and long-term plans based on them. However, it is possible to build on the series of space related projects advised by Professors Wilkes and Campisano.

The vision for the coming years focuses primarily on lunar exploration and development, with some offshoots into Martian or other exploration and settlement. This is in line with NASA's recent announcements, as is discussed in the Miscellaneous section below.

The Lunar Agriculture team has shown that it will be possible to grow food on the Moon without any major scientific or engineering breakthroughs being necessary. That allows the costs of operating a lunar colony to be greatly reduced, due to the lack of a need to constantly re-supply the base with food. Of course, an initial amount of food is necessary for the colonists to set up the base and start growing their own staple crops but this is negligible compared with the alternative of long-term importation of food. Their need for additional gasses can be supplied by the system set up by the HHHF group, which at this point believes that the craft designed by Mr. Klinkman is a viable solution to the problem of collecting gasses from orbit. There is the complication that oxygen is easier to gather than hydrogen but on the moon oxygen is available in the rocks and hydrogen is available in principle if it can't be harvested in space. What is important is that it is believed that eventually hydrogen will be able to be gathered in space. To test this theory a team will be formed next year to look into the issue and to evaluate is Lunar or LEO gathering would be easier. Mr. Klinkman has generously agreed to co-advise the effort, much like he did with the oxygen-gathering team of this year.

Aside from providing for the lunar colony, if the HHHF system can provide both oxygen and hydrogen this would give the essential rocket fuel components. This system will be able to provide all the parts of a propellant for liquid-fueled rockets going further into space. This turns one of the items on the NIAC questionnaire from a practical impossibility to a truly feasible, and practical, device.

The single stage to orbit (SSTO) rocket is a conventional chemical rocket, using proven technology. Current rockets use multiple stages of fuel tanks to propel the craft into space and then more stages to take them to their destinations. This is a massive waste of space. A SSTO rocket uses only one stage, which at the moment is extremely unrealistic. After achieving orbital altitudes, a SSTO rocket has no need for the majority of the weight it is carrying around, as it is no longer carrying the amount of fuel it was at liftoff. If a craft was able to refuel once it had achieved orbit, the range and speed of the craft could be extended by orders of magnitude. If such refueling capability were available, it would greatly speed up humanity's exploration of the outer solar system. Most of the responses from the NIAC fellows seemed to indicate that SSTO rockets were never intended to move a payload beyond low Earth orbit but they were also not considering the ability to refuel using gasses gathered in orbit. The fellows were still thinking of having a SSTO rocket go to orbit and then refuel using fuel provided from the Earth's surface via another delivery method, and thus their conclusions are invalid. The HHHF team's conclusions, if correct, have some far-reaching implications.

One of the biggest holes in the plan is in the development of the Moon. The advisor of the Lunar Development team expects them to finish the project by the end of B term 2007. He has simplified the project from one suitable for 3 people to one a single person could complete. This is a result of one project member completely disengaging from the effort and a second one dating this member later withdrew as well. This abandonment resulted in some mixed feelings towards the project by the remaining student. This member is focusing on the question of radiation shielding. His conclusions will be compared with that of the team next year that was recruited to look into what is required for a lunar colony in terms of energy, atmosphere, and life support. At that point, it will be certain if living and working on the Moon are realistic prospects. For simplicity, it is assumed that one is able to do so and know more about what the habitats are going to require and look like.

Now that the fact that one can indeed live and feed oneself on the Moon has been established, it is time to explain why one would attempt to do so. That is where the fusion teams come into play. The supply of He-3 on the Moon allows (after the development of reliable fusion technology) for the Moon to be completely self-sustaining. It would have the food and also the energy to support long-term endeavors. The excess He-3 can be sent back to Earth, which is approaching the point where we need to find new sources of energy, preferably sources that will last far longer than the fossil fuels have lasted with less environmental impact. In order for continued development on Earth of technology and even for modern society to continue functioning, a constant supply of hopefully cheap energy is necessary. The recent spikes in oil prices have shown just how fragile the economy really is and how dependent on finite energy sources the people truly are at the present time.

At this point, it is believed that one can establish a case for going to the Moon. Getting the word out and establishing a broad base of support for the program still remains to be done. At the time of this writing, the final report from the New Space Initiative group is still to be seen, but it is reported that only 17% of the high school students considered the Moon to be resource-rich, and another 23% weren't sure about the issue in the pre-test, the remainder were sure it was not resource-rich. Then a small amount of information about the subject of He-3 was provided, for about half an hour, in one high school class. In the "post-test" on the same items, 60% considered the Moon resource-rich and another 15% had shifted from not resource-rich to not sure. Only about 10% were completely unmoved by the presentation and considered the Moon not resource-rich.

Interestingly, a majority were already in favor of building a Moon base before their perception of the Moon changed. However, they were rarely in favor of an increase in the NASA budget to do so. After their perception of the Moon changed with the implication that this effort would pay for itself over time, they were willing to increase NASA's budget by a fairly substantial amount. Also, a greater percentage than before the presentation was supportive of building a lunar base.

In short, a massive mandate for lunar exploration and development is likely to follow general public awareness of the Moon's unique resources and their implications. Additionally, the recent discussions and news coverage on the topic of energy independence has set the stage perfectly for laying out this plan. Not only has the current situation been revealed by the NSI team but they have also shown that American public opinion can be hugely swayed by additional information delivered by credible sources.

Even as little as ten years ago, if a person had been asked about energy, they would have scoffed at the need for the discussion. Prior to the oil price spikes no one was particularly interested, considering the last real call for energy independence during an “energy crisis” was back in the 1970’s. Even now, most people do not believe in the practicality of solar or wind energy and for good reason since ground-based power stations are being discussed.

Space advocates believe that a good case can be made for space-based solar energy, where solar input is not interrupted by clouds or nighttime and the energy input per time is greater. It would also be conceivable to turn this space-based solar energy into laser light which is transmitted to the Earth and then re-converting it to electricity. Realistically, fusion power is potentially a safe, reliable source of energy for the coming millennia. Offer that up to the average American and they are likely to ask why the infrastructure has not already been put in place and the system is not in full swing. The question of fusion power is complicated, but as previously stated, a demonstration project, ITER, has been planned and funded. Space based solar is actually an energy method that doesn’t require a breakthrough, but the DOE is not interested. Part of the reason for this is not wanting to turn to NASA to solve the energy problem.

One of the factors that none of the teams really focused on is the fact that technology has always advanced fastest when it is in pursuit of a major goal. If there is no real pressure to do something, then it comes about slowly and over time. Unfortunately, the periods of fastest development have always been in times of war, from germ theory and nuclear energy, to air travel, robotics, materials, computing and beyond. Wars provide a very pressing competitive need for technological advancement. Hopefully, the massive need for energy on Earth will provide a similar stimulus for technological development related to space exploration and development not a war in space. Space technology already has a considerable impact on everyday life, as evidenced by the now familiar commercials on television for the space origin of memory foam for beds. The science of weather forecasting has also been greatly advanced by the use of satellites. The Global Positioning System (GPS) was made possible by geosynchronous satellites. Communications obviously benefits from satellite technology as well. The possibilities for applications on Earth of a manned push into space cannot even begin to be described in this paper, but prior student forecasting papers have concluded that the advent of interplanetary trade and tourism, laboratories in space, and even technology designed to extend the human life span by mitigating the aging process are in the offing.

Correlating Personality with Team Success

This portion of the project has been particularly difficult. It is impossible to treat the cases of group success and failure statistically, as the amount of data received was nowhere near the required number of cases for that. Even if it were possible to take all prior years IQPs into account as well, there would only be 21 from the past and 10 more now and there wouldn't be the same outcome data on each one. If the situation would have been different, dealing with individuals contrary to teams, there would be nearly 100 cases. Even so, there are too few project teams thus far to come to any reliable statistical conclusions. Therefore, each group case needed to be treated individually which is a task that the OCM group was not capable of with the limited amount of data available. As much as the group tried to observe the groups over the course of their projects, the only progress made was that permitted by the groups. This was a result of several constraints:

1. The OCM project started in B term when the majority of the groups being tracked started in A term. This made it impossible to have any data gathered from the first third of their projects that was concurrent, unaffected by memory, and compared to the next phase of activity. It was only possible to get retrospective reports about the first term
2. The teams were supposed to be finishing up during C term, and at that point they wanted to move on from gathering and analyzing data to writing their final reports and were less willing to cooperate with the OCM team unless they were presenting in Baltimore. This left the team only able to really observe the startup and middle phase of the few groups who started in B term, who we had less contact with due to the fact that in B term they were still figuring out what they were doing and gathering initial information.
3. The OCM team was unable to effectively see and use the information provided by the reports of those groups who started in B term. This is because they were writing them at the same time that the writing of the OCM paper.
4. Some groups were trying to hide from the OCM team to avoid the team seeing what they considered to be sub-par performance levels.

These reasons, when put together, indicate that a team attempting what was tried to do really has to plan for a five term project though two of those terms could be half-time. The first four terms should be spent observing the groups who are starting up over two terms and setting up the intergroup communication system, and the final term must be spent writing the report, using the information provided by the preceding terms observation. Practically speaking, this is impossible at WPI unless you are going to finish up in a summer term and pay extra tuition. That is not to say that such a project is worthless, but rather that it requires a different approach. For example, consider the following scenario: a team is formed in A-term with two members. They observe the other teams from A and B terms, and then pass off the observations to two different team members for C and D term. Those four team members then come together in A-term of the following year to present a composite report on the other groups. This is obviously not the ideal situation but it is one possibility. While the OCM team was able to document how well the groups did and were able to report their MBTI types, putting the two truly together for a statistical treatment is not feasible unless it is possible to have everyone to fill out a common questionnaire on team experience or to skip that and focus entirely on outcome that can be coded from a completed report that is possible to get out of the library.

Miscellaneous

This section will contain information that is relevant to but not actually a part of any of the IQPs being conducted. NASA has recently (December 2006) announced plans for a lunar colony to be set up in the 2020's. They plan, much like the Lunar Agriculture team had suggested, settling close to the south pole of the Moon. Presumably, they are looking at the same kinds of things that the agriculture group did: there is a more consistent supply of sunlight which can be turned into energy and used to grow food and there is the possibility of finding water in the form of ice in a deep crater's perpetual shadow near the pole. Having that supply of water, although limited, will greatly increase the chances of success in setting up the first Moon base.

NASA is also looking to have private sector companies assist in the coming years. This is encouraging, especially the union with Scaled Composites' SpaceShipOne flight in June of 2004, the first privately funded space flight. While the flight was more symbolic than functional (the craft reached the edge of space, but did not go into orbit), it offers hope that private companies will eventually be able to do part of NASA's job better in near space cheaper than NASA itself. In fact, this is likely, considering how politicized NASA is. Also, as previously mentioned, NASA is basically using the Moon as a training ground for Mars.

It must be recognized that NASA is by no means the only governmental space agency in the world. The European Space Agency (ESA) and the Chinese National Space Administration

(CNSA) are both planning to go to the Moon. It stands to reason that research and development into both Lunar and Martian technologies will be developed. Private companies will do what they do best: search out what they see as the most profitable venture. Needless to say, some will be in favor of a lunar mission, as the economic case is easier to make, and others in favor of a Martian one, if they are likely to get NASA contracts. With this new space race, the technology will advance at a breakneck pace, and it can only be hoped that these developments will occur not only profitably, but peacefully.

Recommendations for Future Years

It is felt that continued work on this subject is needed in order to provide a more complete picture of what is happening. An Oversight, Coordination, and Management team such as ours is absolutely an essential element, but much thought should go into how it will operate prior to the actual start of the project. A thorough reading of past years projects should be conducted in tandem with observations of the active teams.

Some other teams are also required for the future success of the larger picture of space technology and policy IQPs. One of special note is the team working on Lunar Development. We believe that the shielding question should be separated from development. The two topics are very closely related, for if what is being developed is not shielded, it is useless. However, combining the two topics is ill-advised due to the magnitude of the resultant project. This year's team was unsuccessful, according to the advisor, due to a lack of teamwork and motivation. We believe it to be likely that the lack of motivation resulted from a feeling of being overwhelmed by the project. Everyone has experienced being confronted with a task that is seemingly too large for them to handle, with the result is that no work gets done due to the seeming enormity of the task.

Another team which we believe to be critical is the Lunar Agriculture group. The team for this year investigated whether or not potatoes could be grown on the Moon. Potatoes, yams, and related tubers are a workable, stable crop, but they are not a full meal by themselves. If people are to survive on the Moon for extended periods of time, they need to be well nourished. Other vegetables need to be able to grow on or near the surface of the Moon as well. We will need a team to investigate whether or not it is possible to grow plants with stalks, and other above ground leaves and fruits or nuts.

If we were to have a functional Moon vs. Mars team, it would greatly benefit the overall picture of space that WPI IQPs have developed over the past few years. It should be recognized that such a group is hard to build off of the current WPI base, only one group that mentioned Mars specifically. All other space groups are directly related to lunar topics. To only have a single group devoted to establishing the case for Mars would be folly. The case for the Moon has been laid out carefully, by many teams, over several years. This biases the conclusions towards the Moon, if for no other reason that there is so more information available to the MvM team related to the Moon than there is to Mars. Luckily, there has been a Mars Homestead project at MIT for years, and people coming out of that effort have joined The Mars Society (created by Zubrin) and the 4Frontiers Corp.(co-founded by Joe Palaia). What WPI needs is a team wholly devoted to "catching up" on these developments before doing the Moon vs. Mars comparative study. As a result, many more teams will be devoted to issues related to Mars exploration and development, particularly in the area of the economic and scientific rationale for going to Mars. There also exists the possibility of one or more IQP teams sponsored by 4Frontiers. Apparently, if multiple governmental space agencies are planning expeditions to Mars, there must be some reason for it, and we do not feel that this case has been laid out nearly well enough for the WPI audience.

One final group we would recommend is another Fusion team. The two teams we had working this year each started out looking at one specific kind of fusion each. It remains to be evaluated which of the two is more likely to come about, and which one would be a better use of resources to research.

Final Thoughts

There are a pair of warnings that at this point are all-too-frequently issued:

1. If nothing is done in the coming years to find a new source of energy, the global economy will collapse.
2. If no change is made to the amount of pollution pumped into the atmosphere every day, the global climate will be irreparably damaged.

Venturing into space is one possible solution for these problems. The He-3 gathered from the Moon is potentially a commercially viable, clean source of energy for the coming millennia. On top of that, space exploration will benefit humanity in other ways, such as with the development of advanced communication, transportation, and medical systems.

As with any engineering problem, there are of course other solutions. Let us conclude with an analogy to show how researching multiple solutions is advantageous. When trading stocks, anyone with some basic knowledge of the stock market recommends a balanced portfolio so as to minimize risk. The theory goes that, even if one company (or even an entire industry) fails, you have invested in a sufficiently diverse group of companies that it will have a small affect on your total portfolio. It is the same with our energy problem: we are presented with multiple solutions, from space research that we hope will lead to easily available He-3 that we can use in fusion, to less exotic solutions such as increased solar, wind, and hydro-power generation. Research must be done in all of these areas to ensure that, even if one technology is insufficient to meet the full energy needs of a modern society, the combination of multiple technologies will be able to keep up with demand. In addition, a major topic that the public has not heard about, and which we consider promising, is the space option focusing on the Moon. A new "DoSpace" project active in schools designed to publicize the idea is needed. The implications could be very far reaching.