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Managing the Space Initiative:

Inter-Group Coordination & Communication

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Abstract:

The Space Initiative is an expanding group of WPI IQPs that have been investigating the implications of a renewed world interest in space. To address the rapid growth of the initiative, a management team was created with the goal of assisting teams, transferring information, and helping preserve the overall objective of the initiative. The tools and methods employed by this team have enhanced inter-group communication, revived struggling teams, and helped foster a new generation of space projects.

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1. Introduction

The Space Policy Initiative is an expanding group of Worcester Polytechnic Institute Interactive Qualifying Projects (IQPs) sponsored primarily by the Social Studies of Science and Technology (Division 46). The goal of these studies is the investigation of the economical, social, and technological implications of a renewed interest in space: a technology assessment of a revitalized space program in the United Stated amidst international competition. Projects focus on the "who, what, where, when, why, and how" of topics such as space colonization, commercialization, and emerging technologies. Once this factual understanding is mastered, teams explore the wide-ranging social implications of their topics. The Initiative keeps the individual teams aligned to this common theme in order to perform surveys and analyze the combined results.

The Initiative began in early 2004 and has since grown to more than fifteen reports completed (or nearing completion) and another eighteen scheduled for the 2006-2007 academic year. With only its faculty originator, Professor Wilkes, and Professors Makarov, Pietroforte, and Kazantzis as team advisors, the Initiative quickly became overwhelmed with the amount of effort required to manage and organize the individual teams. Large series of coordinated IQPs are rare, and in many aspects the Initiative was an experiment in and of itself. This provided a valuable opportunity to evaluate team performance, interaction, and dynamics. Thus, the "Management Team" was created in order to assist team coordination and the meta-analysis goal of the individual team reports.

The Management team had a twofold purpose. The first was to leverage psychological type information (MBTI) combined with observation in order to make predictions about the future of individual teams, both during progress and before formation. By learning what combinations of personality types in projects work best together, predictions could be made about which teams had the greatest chances of succeeding. Second, the Management team sought to improve team success by assisting those in trouble, fostering inter-team communication, and keeping teams aligned to the overall Initiative goals. Eventually, the first "purpose" was deemed to require a separate group, eventually created as the "ISIS" team. Hence, this report focuses on the Management team's accomplishments regarding direct team coordination and assistance, rather than the team dynamics study happening in the background.

The Management team was comprised of four self-selecting students, each with four separate goals. Ryan Caron, the team leader and veteran of the Space Policy Initiative, was in charge of enhancing communication between groups by attending meetings and arranging inter-group meetings. His extensive aerospace background, motivated interest in space, and prior work on the Space Policy Initiatve (in a volunteer and independent study capacity) made him the best candidate for his position.

Ellery Harrington (computer science major) was not given any specific initial task, and helped Ryan facilitate communications by attending meetings during the first term of the project. In the course of team progression, Ellery found an ideal opportunity to improve the data gathering and analysis for the Breakthrough teams, and then opted to focus on those areas almost exclusively, especially when the team fell behind due to a shortage of personnel.

Peter Miller (computer science major) was designated to create a public website such that outside viewers could access detailed information about the initiative, and to make finished projects easily accessible to the public. This was important primarily because of unique data generated by the "Breakthrough" series of IQP teams, as well as general interest in certain technologies have received noticeable public attention as of late.

David Anderson (computer science major), was assigned to developing a system for observing and facilitating intra-team communication. In the form of a web application, the intent was to allow teams to exchange ideas and information internally, as well as with other teams, such that the interaction could be statistically documented. This was important to studying the effectiveness of various techniques used for improving team communication. This was initially considered to be part of a prototype ISIS system, but the outside sponsor of that idea did not follow through on their part of the commitment. Hence, a more traditional communication facilitator was developed.

2. Background

The first project of the Space Policy Initiative was a "forecast for the future" of space exploration, which successfully predicted a 2018 return to the moon for the United States. This project team, co-advised by professors Sergey Makarov and John M. Wilkes, compared the original moon race of the 20th century with a possible new moon race between the United States of America and the People's Republic of China. The students comprising the team were not only surprised by what their research uncovered, but that they had not previously known about China's increasingly clear intent on lunar operations. During the team's study, media coverage and talks in technical circles were severely limited. Two years later, NASA announced plans for a moon landing in 2018, and China's interests in a lunar landing (ideally before NASA's return) have been much more pronounced.

However (as noted by Professor Makarov), the team's historical analogy methodology assumed only incremental technological advances. This precluded the possibility of technology breakthroughs, which have played pivotal roles in other fields – meaning further investigation of breakthrough areas had merit. Professor Wilkes suggested creating a "technology assessment" on significant and plausible breakthroughs related to the future of space travel. The technologies, chosen based on cutting-edge ideas, would be assessed and forecasted based on Delphi-type panels[i].

The results of the first Delphi panel effort became one of the Space Policy Initiative's most central and intriguing series of projects, having in turn created a succession of feasibility and implication studies, each of which work from the forecast mode in different ways. Implication studies for both incremental and breakthrough approaches were performed in 2004-2005.

2.1. The Fragmentation of the Habitat Team

Some of the earliest members of the original space race forecast studies dealt with consequences of race runners arriving on the moon. Two projects formed to investigate this question. One was to focus on energy and the sustainability infrastructure of a base on the moon; the other to focus on what a moon base could look like. The latter project ran into trouble early in its timeline when one of its three members was forced to leave WPI for financial reasons. A conflict between Richard Treis (one of the remaining students) and his advisor caused Treis to leave the group. Treis then pursued another project, comparing science fiction portrayal of lunar surface living and engineering studies on the same subject.

The remaining member of the moon base team had little choice but to focus solely on technical aspects, keeping to what was possible with present day technology, entirely avoiding the prediction of technological advances. This breakup of the moon base team meant that there was no unified concept of what a habitat would look like for the rest of the teams in the initiative. The lack of this unified concept made it difficult to propose projects which investigated the social implications of building, sustaining, and expanding such a base.

As such, different teams made different assumptions about what kind of aerospace infrastructure would be needed to support a moon base of 50-60 people; people doing what China's CNSA and NASA seemed to have in mind for their moon bases – mining and practicing for Mars, respectively.

For example, the other team, energy and sustainability, ambiguously concluded that nuclear power would be needed for a moon base. The follow-up team, tackling the same question the next year (with the same advisor), drew a different conclusion advocating Solar Energy. The lunar base infrastructure issue became far more complicated and contentious than expected with each team seeing lunar operations serving vastly different purposes. The implications for Earth varied dramatically and hung in the balance, especially with regards to whether resources on the Moon could be a solution to the predicted energy crisis.

2.2. Lunar Agriculture

Focusing on "The Moon is a Harsh Mistress" by Robert A. Heinlein, Richard Treis (formerly on the moon base team) noted the extraordinary misconceptions that were entertained in regard to establishing trade between the Moon and Earth. Heinlein and others pictured the Moon as an agricultural colony that could be a source of food for Earth. However, they did not give sufficient thought to water shortages, which would make agriculture on the moon so difficult that just sustaining the colonization effort (importing food to a moon base would be too costly) would be too challenging, let alone exporting a surplus. Heinlien also concluded that trade would be necessary for a moon base to be worthwhile, and speculated that one could start out as a penal colony along the lines Australia in order to get an initial labor force. The most important idea to come of this project was that agriculture on the moon would have to be underground, in tunnels, without direct access to sunlight. This problem inspired the "Bionic Leaf" concept which went into the Breakthrough Delphi study.

2.3. Lunar Legal

Another team managed to approach some of the questions and implications of colonization in the form of a role playing game. *Moon Race: The Game*, through a model UN debate on the future of lunar claims and policy, addressed the ambiguity of international law governing activities in space and how current laws curtail operations of economic value on the lunar surface. Using the original space race forecast as a fictitious history, the team sought to raise awareness of the issues surrounding a return to space[ii], and particularly the moon.

2.4. Closing

The seven projects succeeding the original moon race forecast which were completed prior to the 2005-2006 academic year were largely a success, and garnered interest in space policy related IQPs at WPI. The star project in this regard was the Social Implications team which assumed no breakthrough technology, and still made breathtaking predictions about helium trade and medical advances that were sufficiently valuable enough to pay for the development of the Moon. This growing interest provided new questions and problems for future projects. The only unfortunate aspect was a severe lack of discussion about commercialization. A tendency to simplify questions relating to commercial interests in space trivialized the importance of the subject. Though unfortunate, this lapse left a large field of study open for future initiative projects. Students were available to delve into them, as the initiative expanded from twenty-one to forty-five (or, seven teams to fourteen) the next year.

Professor Wilkes had advised (or co-advised) all Initiative projects during the 2004-2005 academic year, which proved invaluable in keeping the disparate teams on track for a meta-analysis. With fourteen projects slated for the 2005-2006 academic year, such an arrangement became impossible. The management team was then created as a way to cope with the unwieldy task of maintaining a common theme and coordinated goals over a large number of projects. The ultimate goal was unchanged: to produce an overall technology assessment of the social implications of a space technology push associated with the results of the many projects to date. However, the Initiative was now expanding on the controversial ideas of many technologies exhibited in the breakthrough feasibility study.

3. Methodology

Early on it was decided that from a social sciences perspective, the teams themselves would be subjects of an academic investigation. By monitoring team dynamics, noting academic progress, and gathering information on cognitive style, predictions could be made on team performance and the potential of a group soon after it was formed. For example, predicting the ability of individuals to work in a group could greatly improve the process of creating teams. These hypotheses could then be verified or refuted at the completion of each IQP, based on whether the teams' outcomes matched the predictions.

A prior study of WPI MQP teams had tested a theory developed at Stanford. The theory stated that ideal three person teams should include a "technologist" (MBTI type ISTJ), a "synthesizer" (MBTI type EN), and a "manager" (MBTI type ET) or "facilitator" (MBTI type EF). The WPI test of this theory had not gone well; "NJs" worked as well as "SJs" in the technologist role. Furthermore, the technologist was only valuable on "innovation" teams; others working on state-of-the-art technology did not seem to need an anchor person for keeping the project grounded.

However, Space Initiative teams were all visionary – pushing technology to the edge with breakthroughs and their implications. Rather than assume that the MQP findings applied to the IQP teams, it was decided to an aftermath study to verify the findings. Thus, the teams were not created as to produce any particular combination of cognitive styles.

The information gathered from team analyses had benefits for the management of future teams (although it would not be used to manage these teams). However, an inherent conflict between the management team's two objectives arose: was the job observation of the other teams, or assistance? Based on the initial rough beginnings for some of the projects, and the difficulties in relaying the findings from the previous teams to the current ones, it became apparent that much more than observation would be necessary. As such, management focused on assisting the teams whereas the ISIS team formed to take over the group dynamics study portion of the project.

The interactive management team, advised by Professor John Wilkes, began by intending to monitor all of the Initiative's teams. When it became apparent that Management was only receiving status reports from teams that Professor Wilkes directly advised, Professor Wilkes turned the Management's focus to teams he thought were more in need of their attention.

The Management team's subsequent attempts to put evolving projects back on track with their initial Initiative objective were met with resistance. One team in particular had drifted considerably from the Initiative's proposed direction. The advisor had turned the project in a direction closer to his background, without realizing its significant place in the overall picture. It quickly became apparent that if the Management team wanted the project to holds its initial issues and questions, then Management would have to be proactively involved from the start. Instead, the Managers had little leverage with the team (compared to the advisors), and were limited to stating, "as a group trying to do a larger meta-analysis, we were hoping you would try to answer this question," and hoping for the best.

The method the Management team chose for keeping up to date on projects was to have at least one member sit in on each of the teams' meetings. With a representative at every meeting, the Management team attempted to stay current with the teams' progression and provided outside information channels from other teams and sources. The Management member attending a given team's meetings took notes and tried to keep track of metrics like attendance, division of labor and effort, possible leaders or visionaries, and the excitement or interest the group had in their project. Using this data, the management team was able to broadly classify a teams' state as "formulation, execution, or reporting," as they progressed.

However, it became surprisingly difficult to attend every meeting of all of the teams, especially with only four members on Management. Due to scheduling conflicts and a lack of man-hours, some teams were often (and repeatedly) missed completely. Others were attended sporadically, and a few had uncharacteristically strong ties to Managers attending, and got special attention. The Management team also met much apathy toward the larger picture, and was often not informed about changes in meeting times or locations. While some teams welcomed the additional information resources, others considered it an intrusion. There were also cases where the advisors themselves were not clear on the role of the Management team, despite multiple attempts at detailing the nature of their efforts. This led to some rather awkward and unproductive meetings that, from a management perspective, were sometimes costly in momentum and difficult to recover from.

In an attempt to make up for the lack of coverage, the Management team attempted to alleviate some of the workload by requesting that the teams submit periodic status reports. This proposal was met with scattered response and largely left the management team with less information than they had been able to originally gather in person at sporadically attended meetings.

3.1 Fostering inter-team communication

David Anderson's project was originally what would later become the focus of the ISIS team. He intended to develop a software system for project management that would account for cognitive type information. The system would allow the Management team to follow and study the flow of work for a project, with the addition of cognitive data to see which types took certain roles, as well as who talked to whom. However, this notion soon ran beyond the realm of reality; finding communication paths between individuals proved to be a formidable undertaking. Due to various circumstances, this project became largely separated from Management and David was placed on the Management team.

Mid-year David received another chance at working on software for the Space Policy Initiative in the form of a system solely to foster inter-team communication. Due to the difficulties involved with attending the various teams' meetings, the Management team decided to create a system that would encourage teams to share data and communicate with each other. Despite his efforts, the system never saw use. Having been introduced half way through most projects' lifecycles, students were reluctant to undertake learning a new system and changing established their methods of communication. Obviously, it was also not possible to enforce the use of one method of contact. Furthermore, it was realized that without the efforts of the Management team, there would be very little communication to measure. This created a dependence on the Managers, who generally passed on information through channels as they saw fit, further making external inter-team gatherings rare.

3.1.1. Original Project Goals

As stated earlier, the original goal of David's project was to combine team management and communication with cognitive type information as a web-based software package. This would provide a framework for assessing team dynamics and efficiency based on data from surveys such as the MBTI. This framework was largely broken down into three major portions. The first specified that managers should be able to assess, interact, and share/access cognitive style information. Expanded, managers could create surveys, share milestone reports, give tasks, et cetera. The second portion of this framework was designated to intra-team management. Each team would get a specific area to track and revise files, hold discussions, manage tasks, and track milestones. Last, inter-team communication would allow different teams and their members to share files, information, and ideas.

This project was initially proposed as the ISIS project, and a third party software developer, Jesse Hurley, was brought on-board. The plan was to develop the software for Jesse's company, which purportedly was working on similar software, and then bring it to use during A term of 2006 to test on the IQP teams. Meanwhile, David focused on rewriting, automating, and centralizing the Breakthrough Survey website questionnaire. This eventually led to Ellery Harrington's massive overhaul in the following year.

As part of this effort, the "space.wpi.edu" server was built and dedicated to the Space Policy Initiative. Running Linux as an operating system, Apache as a webserver, and MySQL as a database backend, it was designed to accommodate any Space Policy project which required additional services, such as website hosting or a file repository. It was also intended to run the future team management software as well as the public website to the Initiative.

Unfortunately, talks with Mr. Hurley were largely delayed and unsuccessful over the summer, and eventually the project was abandoned. It was later learned that there was a falling out among four WPI students who had originally formed the company, and the organization could not undertake a new initiative or spare any resources. The original idea became the sole research task of the ISIS team. However, it was deemed that the specific inter-team communication abilities of the proposed software could still be very useful to the Management team. Thus, development continued during A term.

3.1.2. The Resulting Product

Inter-team communication was founded on two goals: members on teams should be able to easily discuss information with other groups, and teams should be able to easily find information and milestone reports from other groups. However, as development did not start until A term (when projects were beginning), many of the initial features planned were dropped for lack of development time.

Eventually, it was decided to change focus from developing new software, to studying the effectiveness of attempted methods of inter-group collaboration. As such, a small system, dubbed "IQPForge," was built upon pre-existing software. The initial choice for collaboration software was "phpBB2," a well-known and open source web-based bulletin board system. Specifically, phpBB2 had the ability to maintain users, groups, and user to group relationships. This membership hierarchy extended to ownership of bulletin boards. Each group was primed with the current team members and the team's advisors.

Each group was given an initial category for their project. Each group's category contained three bulletin boards ("forums") – "Open Discussion," "Project Discussion," and

"Tasks and Milestones." The latter two were only visible to the group members, as intended for private use. "Project Discussion" was to be used for projects to discuss general internal topics. "Tasks and Milestones" was for team members to arrange and detail tasks, discuss them, and then lock them once completed. Finally, "Open Discussion" was for other members in other teams to give input or share ideas.

The forums were also intended for the Management team to better organize themselves. Each member of the Management group had the ability to read each team's internal forums. This way, managers could offer input when requested and gauge the forum usage and progress of a particular group. Furthermore, the managers had their own internal boards. These saw the most usage from team meetings. Managers could maintain ongoing discussion threads with updates on team meetings, even posting recorded minutes. Managers could also send global e-mails to all team members and advisors.

As an access point, a public front-end to "IQPForge" was created. This website featured links to each of the project's categories in the bulletin board software, links to important documents, and news. More importantly, news postings were directly streamed from the bulletin boards themselves. This meant that any user could submit inter-group news, and a manager could easily approve it for public consumption. News was also available through RSS feeds (which are often preferable for integration into e-mail clients). Currently, this access point still remains as the viewable portion of Space Policy Initiative's public website.

Lastly, another major piece of software was integrated. Also open source, "The Horde" is collection of extensive simple, group-oriented, web-based management tools. Using the same group and user hierarchy as the forums, collaborative calendars, note-taking, and tasking software was enabled. This portion was titled “myIQP,” in order to convey similarity to “myWPI,” a similar software setup used by WPI.

3.1.2. Usage by Teams

Unfortunately, the “IQPForge” did not receive good a reception. From the handful of non-management users who attempted to utilize the bulletin boards, there was no interaction seen. Users did not care to post public information about their project or interact internally on the message boards. As such, promoting the system was largely abandoned during the final term of the teams’ lifecycles.

Pinpointing exactly why users did not receive the idea well is although largely obvious, also multi-faceted. The primary reason can be attributed to the late start the project had. It was not publicized and finalized until at least mid-B term of the 2005-2006 academic year. This placed adoption in the exact middle of the majority of teams’ timelines. Many teams were understandably reluctant to break from their normal communication patterns to accommodate an experimental idea. After it appeared that usage would not be high and projects would soon be wrapping up, it was no longer meaningful to aggressively push usage.

Another reason for the lack of use can be seen in the overall apathy witnessed towards the Management team. This trend was shown to be increasing over the three term period, with attendance to the overall team meetings dwindling rapidly over time. This observation had already been made before IQPForge’s launch, and as such, expecting it to be widely accepted amongst teams was much too overly ambitious.

Finally, team members appeared disinterested in the concept itself. This, however, contradicted initial expectations. From observing statistical balances of MBTI types, it can be seen that WPI has a typically introverted community. Only seventeen of the forty-five students were extraverts, and only one team was comprised of all extraverts. Thus, it was assumed that mediated, private electronic communication would be more appealing to students, especially if the students did not know each other beforehand, or were not attending the major group meetings (and thus not communicating physically). This expectation was proven wrong.

3.1.3. Usage Survey

In order to understand why inter-team communication had largely failed, a survey was created in order to assess two fundamental areas that relate how people of different teams interact. The first portion of the survey dealt with "communication relationships." Each person was asked to identify each *other* person on any of the other teams that he or she could identify with. The identification was in the form of knowing the person before the project, meeting the person through the project, or coming to trust the person as a reliable source of information through the project.

Second, each person was asked to identify their communication patterns with the above people. Specifically, how often they communicated with people inside and outside their team, and with what methods they used to communicate with both. As a tack-on to the survey, team members were asked which other projects they knew information about – projects they thought might be relevant, and group presentations they had seen. Finally, in this section, people were also asked if they knew of the existence of the IQPForge idea, and whether they thought it was useful.

Ironically, response to the survey was somewhat better than response to IQPForge. Unfortunately, the sixteen results gleaned weren't statistically enough to generate conclusive findings. However, this number is spread across ten of the fifteen teams, which is enough to note a few interesting trends.

Cross referencing MBTI data with survey respondents revealed that, of the fifteen people with correlating MBTI data, ten were introverts (66%). Of these ten, only three did not know at least four other people on the overall projects beforehand. More interestingly was that most respondents claimed that they communicated primarily over e-mail, in their group meetings, and via instant messaging (with scattered replies of specific in-person meetings other than regularly scheduled ones). This lends to suggest that the theorized correlation between cognitive type and usage of electronic systems was either misguided, or ultimately unrelated as to why it was not used. The typical by comment was that the system was not perceived as "useful."

Surprisingly, most users replied that they had at least somewhat of an idea of what the other teams were doing, and twelve of the sixteen respondents listed at least two teams they specifically thought were relevant to their own topics. Disappointingly, most users noted that although they knew the IQPForge website existed, they did not use it. Most users replied that they met with their team members at least weekly, and with outside team members at least monthly. This was expected at the start, but later doubted. As such, it was relieving to find that contact had not dwindled – only the ability to monitor and measure exchanges had. The efforts had not gone to waste.

3.1.4. The Future of Inter-Team Collaboration

While the IQPForge idea was overall poorly timed and poorly received, it remains to be seen as to whether it is a potentially effective communication tool. The data from the survey suggested that prior communication patterns between introverts are important, and that they do use electronic communication. The concept of IQPForge is therefore not necessarily useless, but rather represents a change in an established pattern that has to be justified. There is a problem somewhere else in the chain of communication that Management established which must be addressed in order to keep Managers informed. Most likely, the success of IQPForge is largely dependent on the general attitude of the groups – and whether they feel that the channels it provides are efficient enough to be useful. If the next iteration of the Space Policy Initiative were to use similar facilities from the beginning, adoption would be more likely, but ultimately still dependent on the groups as a whole. If a selected group was chosen to publically give their progress reports to the others over the system, it would help generate the traffic necessary to launch the idea.

In a relatively small community such as WPI, small to medium sized in-person group meetings are worth pursuing, and more promising, than overly-organized electronic communication. However, the goal of group meetings should be to establish the electronic alternative as the need for larger meetings tapers. It would then be understood that the group should either attend the bi-weekly (smaller) meetings, or report via the electronic system (even at the cost of learning a new set of software rules).

3.2. A Public Portal - Making Results Available

Peter Miller's original project, entitled "The Medium and the Messenger," involved a report reviewing the Space Policy Initiative thus far, its origins, an overview of the completed projects, and the conferences it generated. In addition, he intended to create a website to parallel the paper, offering the same information in two formats. These two components would then be followed by a study, having people read the paper and visit the website. Half would see the paper before the website and the other half vice-versa. The participants would then be asked to respond to a questionnaire with the goal of determining which method of distribution was more effective; hence the project's title.

Peter's role in the management team was more observatory, enabling him to get an overview of the initiative as a whole and keep tabs on the status of projects. While working with Management it became apparent that the website portion of the project was essential to the continuing success of the initiative. Not only would it be a way to inform the larger community about what we were up to, but a way to recruit interested students and make useful contacts in other organizations. However, it would have to be more extensive than had first been envisioned.

Instead of a web-enabled version of a paper, the website would have to be the world's window on the teams' progres. Besides describing the origins of the initiative and how projects related to one another, it would have to offer summaries of completed projects with reports, proposals, and information about projects in progress, where the teams' members could post news and updates. There would also be opportunity for the public to make comments and ask questions. A section detailing prospective projects would give interested students or potential advisers an idea of what projects in which they might want to participate. An area for events would provide schedules for upcoming conferences, and pictures and other media could showcase past events. Lastly, the website would act as a gateway for other web-applications like conference registration and surveys. Particularly, the Breakthrough Survey and its related data would be a center attraction. Although less of an immediate concern, lofty ideas about other possibilities, such as a place to provide information and reviews of related literature, were discussed. In summary, the Space Policy Initiative's website would be the one stop resource for all things related to WPI and space.

3.2.1. Technology

With the new requirements in mind it became apparent that a content management system (CMS) would be necessary. Not having any budget, open source software would have to be used. An additional requirement was that for sustainability of the project from year to year, the software had to be easy to use, such that someone with little technical knowledge could maintain it. It was especially important to have a simple and intuitive interface for project team members to contribute to their project's information. Of the several CMS solutions investigated, most systems seemed overly complicated for a less-technical person to maintain. Based on initial impressions, ease of setup, and a recommendation from a friend using it, WordPress v1.5 was selected.

As a blogging tool, WordPress allows for the easy creation of new articles. Data is entered into a simple form with fields for the title, category, and body of the article which is submitted by the press of a button. The software takes care of adding the article to the website and creating a new page for the article. It allows users to easily filter content by date, category, author, or other attributes. It allows the administrator to add other authors and easily manage their access and permissions.

WordPress supports what it calls "Pages" in addition to standard blog features. Pages are how static content is easily managed. An example of this type of static page is an "About" page, which contains standard info that should be generally viewable. WordPress also supports a "Theme" system, which gives a site a unified look and feel and can be changed with little knowledge. Themes are how the look and navigation system of the website would be customized.

The idea was to use Pages for project information, but associate each project with a blog category. Articles posted under that category would be displayed under a news section on the appropriate page. To facilitate this model, more finely grained control of user permissions in WordPress were investigated. User permissions needed to be restricted to limit project team members such that editing and writing about their project would be possible, while editing the content of other teams would not be allowed. No "plugins" (addons) provided this specific functionality. After finding a combination of plugins that solved a similar restriction problem, the plugins were then modified to allow the site administrator to assign a user to a specific category.

One of the modifications required to make this work with the aforementioned organizational method was to change what a user would see when he or she wrote an article. The original plugin simply hid any categories a given user didn't have access to. The problem with this method was that it would hide parent categories, which the user couldn't post within. But those parent categories were what distinguished two sub-categories of the same name. This was solved by instead both displaying and disabling all categories for every restricted user. The user could then see all categories, but be unable to select any of them, while the one they had access to was automatically highlighted and selected for them. This setup assumed that users with restricted access were only attached to one project and thus one category.

WordPress also had an option that could turn links to specific articles or pages into something more memorable than an identification number. However, in WordPress 1.5, this feature did not correctly distinguish between two pages by the same name -- even if they had different "parent" pages. For example, "/completed-projects/breakthrough-study" and "current-projects/breakthrough-study" would send you to the first page, disregarding the page hierarchy.

Being able to make this distinction was an important component in generating a navigation menu with categories and sub-categories. This was solved by modifying the code in question to handle this specific usage.

The default theme in WordPress was a very simple centered column with a header consisting of the website name, a simple right-side menu, and a list of articles. One of the first customizations made was to make the banner reflect the title of the current page. The next step was to enclose the current template within an extra top banner and a right-aligned navigation menu. Figure 1 demonstrates this addition.

Figure 1 Initial WordPress Theme Customization

WordPress prepared the release of v2.0 of their software during this time. The new software had enough improvements over v1.5 to warrant an upgrade. The updates included functionality to handle some of the permissions problems previously worked on, as well as fixing the problem with distinguishing two pages with the same name based on their differing parents. The latter was of particular importance since the prior solution was poor.

The main website was upgraded after successfully attempting the upgrade on a test website. Unfortunately, the upgrade failed, corrupting the database in the process. Apparently the plugin for access control rights had slightly modified the database, and the automated upgrade was unable to understand and compensate for the changes. The theme, residing outside the database, was unaffected, but the project information previously entered was lost. While all the data was still available in their original forms, it all had to be reentered into the system, highlighting the importance of data backups.

Another step toward making this easy for someone to manage was having the menus generated based on page parent-child relationships, so if a new project was added, all the formatting and navigation would be taken care of, leaving only the content to be developed. This was accomplished with custom PHP code which would be executed from within the theme. It was important to have a straightforward navigation interface where the user could quickly get to any project from the front page; however, simply listing all of the projects on a menu would be too long a list. This problem was solved by implementing a menu where, when the mouse is moved over a category it displays, submenus are displayed consisting of the projects in that category. The JavaScript program “Transmenu”, by Aaron Boodman of www.youngpup.net provided the core of this submenu system. The new theme with dynamic JavaScript menus can be seen in Figure 2.

Figure 2 Second WordPress Theme Customization

3.2.2. Categories

With the technical problems overcome, resources could be focused on how to actually present these projects to the public. The precise problem was how to organize information in such a manner that would be of the most value for people unfamiliar with the projects; this was quite challenging. The titles alone were not descriptive enough to assist someone with little prior knowledge. Devising categories for the completed 2004-2005 projects was straightforward. However, when adding the 2005-2006 projects already underway, it was realized that very few of them fit, since they were inherently cross-discipline. This may have been resolved by creating new categories, but it was important to avoid the ambiguity of similar, but not identical, options. The final category structure, shown in Figure 3, is a product of Professor Wilkes's understanding of what the projects content (regardless of its title) can be broken down as.

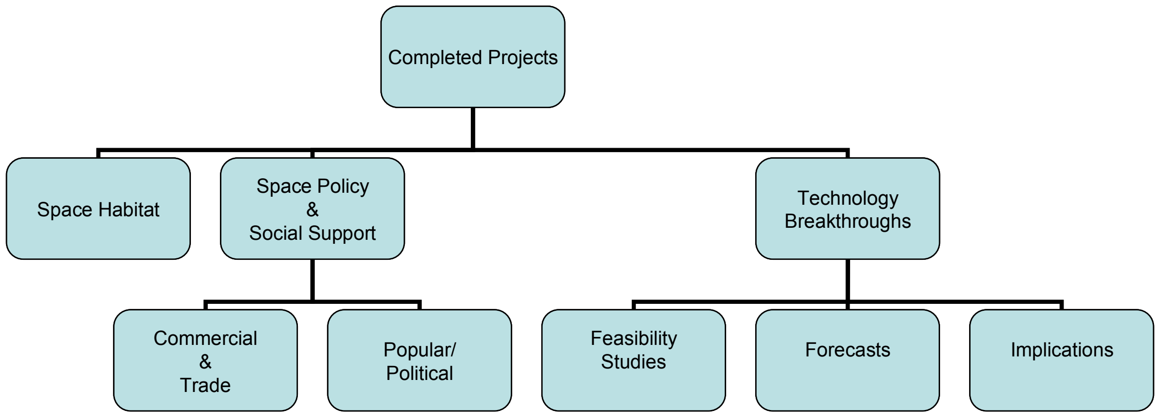

Figure 3 Category Structure

3.2.3. The Completed System

The completed system was a way of distributing completed reports to the public and to provide references and background to future project teams. It was also a forum for communications to announce presentations and related conferences/events. The interface was easily usable by whomever the initiative placed in charge of report gathering and public relations.

Creating the system by customizing the WordPress software had met a degree of success, but it was not an ideal solution. The problem was approached with the idea that taking something simple and customizing it would yield a simple product which would meet the initiative's needs. Unfortunately, starting with a simple base invariably requires the addition of more complicated features as the project evolves.

3.3. Initiative-Wide Meetings

The Management team was able to attend regularly scheduled team meetings. Unfortunately, many teams were not consistently available, and a small number never even replied to Management's requests. Most teams were difficult to hold meetings with due to scheduling complexities and/or the inherent apathy of teams communicating their meeting times with Management. For this reason, weekly mass meetings were organized for B and C terms. This would allow for groups to hear other groups present and to encourage a discussion across project lines. This technique worked very well when there was good attendance, but the high turn-out was difficult to sustain in the long run, and the meetings became rather poorly attended towards the end of the year. The meetings, scheduled in the evenings to accommodate the highest number of people, were replaced by lunch time meetings to better meet professors' schedules. This too was a problem for attendance – many students were either unable or did not want to attend these meetings. Several attempts were made at persuading people into attending, but those who were able to attend may have felt that the presentations were not beneficial to their own work, and worse, might reveal that their own progress was not satisfactory. Thus, many concluded that the meetings were not worth attending.

The large weekly meetings, even with a lack of students, provided a very good exchange medium with the Management team. Many of the attending students and professors found new information relevant to their own projects or at the very least, interesting space-related information of which they had not been made aware. In this regard the meetings were successful, but only to the minority of the teams that attended.

3.4. Assisting the Breakthrough Team

In the course of attending meetings, it was apparent that some groups were succeeding with their intended goal, but others needed assistance. One group that was struggling, largely due to limited time and personal resources, was the Breakthrough group – the team which had the goal of completing a Delphi study of space-related breakthroughs that could occur during the next fifty years. Only one person remained on the team after another had done his work over the summer. The study was also lagging behind schedule because of the group's large agenda. Since the Delphi studies are a significant cornerstone of the Space Policy Initiative, the Management group provided substantial assistance; it was not acceptable for this team to fail.

The Breakthrough team's goal was to deploy a Delphi study of possible new technologies. The full process involved several waves of data collection. In this case the first wave was a survey gauging reactions to 20 space-related breakthroughs. By deploying the survey over a broad range of audiences, the breakthrough project hoped to achieve a better understanding of the likelihood and significance of such technologies. In one of the meetings with the breakthrough team, it became apparent that they needed a different, more elaborate method for analysis than looking at average responses. With Ellery's prior experience in graphical web analysis tools, he was chosen by the Management team to work closely with the Breakthrough team on a better analysis, display, and data capturing system.

Before the 2005-2006 incarnation of the Breakthrough project, the reports were substantially lacking in data analysis; little more than a simple average for the data sets was available. This provided very little information because a certain average can occur in several different situations. For example, a polarized response and a consensus will be reported as the same in some instances. Furthermore, the averages do not relate the three dimensions that were reported. Since each question asked for a significance, a likelihood, and a time period, it was important to see the correlations between those parameters. The most useful analysis system would present the data of all three of these dimensions in an easy-to-read fashion. Therefore, for the significant efforts in the data gathering to be worthwhile, the analysis had to be expanded. It also needed to be automated, such that time would not be wasted on performing statistical analyses manually.

Following the rejection of averages, it was necessary to develop a better tool for analyzing respondents' outlooks. Histograms were useful in analyzing individual dimensions , but did not provide a relationship between the noted three dimensions.

The solution was to develop a new type of table, called a "cross table," which related the three dimensions. Its four columns represented a reduced set of the combinations of significance and likelihood. The four rows are the four choices for time period: Early, Middle, Late and Never. The resulting table was marked with percentages in each cell, and the cell was colored to further illustrate the difference in cells. In some cases, the time period was not crucial, so the totals of each column are listed at the bottom. Figure 4 shows an example where the majority considers the technology unlikely, but the decision is split over insignificant and significant.

	Insignificant & Unlikely	Insignificant & Likely	Significant & Unlikely	Significant & Likely
Early	0.0%	0.0%	6.3%	0.0%
Middle	18.8%	6.3%	6.3%	6.3%
Late	25.0%	0.0%	18.8%	0.0%

Never	0.0%	0.0%	0.0%	0.0%
Total	43.8%	6.3%	43.8%	6.3%

Figure 4 Example "cross table" with a majority considering a technology unlikely but undecided on significance

Since the significance and likelihood is based on a scale of 1-6 and the cross tables only show significant/insignificant and likely/unlikely, some "resolution" in the data is lost to improve human readability. The tables usually split the two categories between the 3 and 4 selections, splitting the range in half. The option of splitting the tables in smaller steps was retained so a more focused analysis could take place at any time.

The cross tables provided a useful summary of the responses, but the exact values of responses was lost. For this reason, they should be used in combination with histograms and other analysis techniques to observe the trends. To add more meaningful information the comments gathered by the survey, which so far had barely been used in the analysis, a user could put their cursor over the bars of a histogram or the boxes in the cross table to see the comments associated with those values.

The cross tables and histogram and their management tools are implemented with PHP and connecting to a MySQL database. The cross tables are generated with HTML, and the histograms are generated graphically with the GD graphics library for PHP.

In addition to analysis, the Breakthrough team needed a better method for obtaining responses to the survey. Paper surveys, the previous primary method, required a lot of coordination and manual entry into the database. Emails had also been exchanged to fill out the survey, but that method didn't lower the coordinating and data entry requirements. There was previously a web based entry system, but it had some limitations, and was only applicable to certain groups, not to mention a questionable reliability track record. That web system was replaced with an entirely rebuilt package that included a respondents' demographic information in addition to their technology responses and comments.

This new input system has proven to be a success with people from many backgrounds. Combined with the the new analysis system, these web tools are now an integral part of the Breakthrough project, increasing interest in the project from WPI students and outside groups. In the future, data is likely to simply flow periodically from people who want to compare their results to a given panel. This will end up creating new panels as well as a general population norm.

3.5. Annual IASTS Baltimore Conference

The Space Policy Initiative has been represented at the annual IASTS conference in Baltimore, MD for two years running. WPI's presentations at the conference require a substantial amount of time from all the participating teams in the middle of C term. To some extent, the whole Initiative is an effort to use classic STS concepts that weren't receiving much attention at WPI when presented in class, and introduce students to them in the context of project work. When offered as a course, learning to do technology assessments didn't attract much of a class, but the Space Policy Initiative has two dozen students working precisely on various aspects of that subject. The difference is in that the technology assessment is being applied to something with high interest, namely space.

IASTS is a social science organization and as such is not focused on space. The Space Policy Initiative presentations draw interest at the IASTS conference because of the methodology used in the Initiative's analysis, particularly the use of cognitive type information. The projects are the unique with regards to merging a Delphi study with the cognitive style information for the panelists in the form of the MBTI data. It is that side of the initiative that was showcased at the IASTS conference this year.

The IASTS conference has the additional benefit of being a deadline that forces teams at a standstill get moving again. Four Initiative teams attended the spring 2006 conference, and they produced substantially more results during the preparation than at any other time. However, the preparation for the conference was both a blessing and a curse. Both the Space Station and NIAC teams found it hard to finalize their project after the presentation, at least one member in each case not understanding what else there was left to do on top of the conference results.

In the NIAC team's case, which gave an analysis of ten cases in their February presentation, they had trouble rethinking their results when four more experts responded a month later. With the fast approaching deadline of graduation, the additional cases were forgotten in their data tables, but noted in the sample size. This discrepancy created considerable confusion as to whether their results were actually final or not.

3.6. Planning for Next Year

In previous years, team assignments were done manually by Professor Wilkes, with fairly little interaction from the students who were to be participating in the projects. Some students arrived as teams beforehand, and one team specifically requested a given topic, but these were rare occurrences. Most were just assigned to a project in a pseudo-random fashion, and then shuffled to other groups as openings appeared. The resulting teams were mostly successful, but for the majority there was no indication that they were particularly interested in the specific topics that they were assigned to, and some were clearly disappointed. The "longevity" team disbanded and quit after assignment, never having considered Space an area for a biomedical project.

To improve this process for the next year, the management created a feedback system to gather the preferences of potential participants. This involved a new web application, made by Ellery Harrington, specialized for this purpose (although some of the underlying code was modeled off of the new space survey system).

The interface was a simple list of all projects, each with a paragraph length description of its intended goal. Students were asked to rate each project on a scale of zero to four, where zero indicates "not interested" and four indicates "first choice." Comment boxes were also provided so that the students could give their reasons for picking the project they did. A general essay box was also given for a short description of their reasons for wanting to do a space policy IQP. The interface also prompted the students to confirm their contact and background information, such as their email address and major.

With the responses to this survey, Professor Wilkes was able to devise the teams with more interaction from the students, and a stronger understanding of their preferences. In some cases, entire groups of students (who already knew each other) were placed on a single team, but in most cases the teams were formed purely on the preferences from the survey. Seventeen of the twenty-five students using the survey were assigned one of their highest rated projects (four). Six were assigned to a project rated by them as three, and only two were assigned to a project rated as two. No students who used the web interface were assigned to anything they expressed no interest in.

The implications of this are significant. It is likely that by assigning students to projects that they themselves prioritized, the Space Policy IQPs will have substantially better outcomes, as well as greater enthusiasm than seen in the current teams. Furthermore, when students pick their own project, they are more invested and interested in the work that they do.

Of course, this meant that MBTI data would not be used to form the groups – and it is now known that having an NJ or SJ cognitive type on each team does affect the advisor's private rating (not the public grade) of the team's performance. As it turns out, the students' group performance ratings are negatively correlated with the amount of MBTI diversity in the group. This indicates while diversity is good in producing academic results, it is not desirable from a personal standpoint. Next year, it will have to be decided whether to share this information or not, and whether to try to intervene to improve the group dynamics. If there is no natural "anchor" on the team, perhaps someone else can assume that role if asked to do by the advisor, and designated as such by the group's approval.

3.7. Transitioning From One Year to the Next

The transition of one year to the next is typically problematic. In order to better understand their own projects, the new teams must receive an overview of the work done in previous years, as well as get detailed information about the projects that serve as the basis for their own work. The latter requires individual meetings between the groups from the different years. The overview can be facilitated by a series of short presentations on the topics.

In spring 2005, a conference was held to facilitate this process. Members of the WPI faculty, outside students, and several professionals were in attendance. While only some of these people had made formal presentations, their presence made for lively discussion and question and answering sessions. The conference concluded with a role-playing game built by the Moon Race IQP team. It involved students representing various nations in a hypothetical 2025 space race. The active recruitment of teams from the current and upcoming projects encouraged attendance.

The 2006 conference lacked that aspect and only presented projects with a series of 30-minute presentations. This allowed the conference to handle more teams, but took away much of the interactivity. Attendance of the conference was low from new teams, which can be attributed to the lateness of the announcement, as well as the date of the conference being very late in the term. It was hoped that the representatives from the Mars Homestead Project would further entice attendance, but even this could not overcome the other factors; the end of term crunch was in progress, and no one could spare an entire Saturday except the organizers.

4. Team Summaries

4.1 Helium-3 Harvesting

Helium-3, touted by its proponents as the ideal fuel for fusion reactors, could solve Earth's impending energy crisis. However, the only significant “local” source of He-3 is in lunar regolith, deposited over the eons by the solar wind. Harvesting this fuel and returning it to Earth requires substantial space infrastructure. Current research efforts into the fusion problem need much more funding, since many experts in nuclear engineering circles claim that fusion will not be available by the time that oil reserves are depleted.

Nevertheless, this project involves the dramatic issues surrounding humanity's energy consumption, and the need to move away from an oil-based economy (as a fuel source, oil will remain vital for its use in the creation of polymers/plastics). Alternative energy sources, with the exception of the nuclear fission possibility, cannot physically have a high enough yield to replace oil. Space based solar power platforms are another exception, but such an infrastructure would require a launch cost reduction on the order of what could be provided by the space elevator, or the capability to produce such platforms from lunar materials.

Vacuum pyrolysis, the technology behind the harvesting of Helium-3, has been thoroughly investigated since it can also be used for harvesting oxygen for use as air and as a propellant. However, separating Helium from the other released gases is energy intensive, as is the separation of He-3 from conventional He-4, which requires cryogenic pumps.

He-3 has the highest theoretical efficiency of any fusion reaction, but it also requires the most energy to sustain. A deuterium/He-3 reaction is almost as efficient and is easier to initiate and sustain. If and when fusion can produce electricity, it will initially be done with deuterium-tritium. As such, it is possible that fusion will not progress to He-3 reactors. However, the use of either deuterium/He-3 or He-3 reactions provides a tantalizing possibility that a deuterium/tritium reaction cannot; the direct production of electricity without powering a turbine. By bypassing the turbine, the inherent mechanical and thermal losses typical of power generation are omitted, theoretically increasing the power yield by a factor of two.

Interestingly, on the Moon, only He-3 is available. Combined with space's inherent vacuum (required for any fusion reaction), He-3 may not provide Earth with power, but it might provide power for space applications, particularly for lunar infrastructure and production. Such a power source also enables very high thrust – high-efficiency electric propulsion drives akin to what Dr. Robert Zubrin describes in his definition of a Type II spacefairing civilization.

MBTI Data for Group:		Helium-3		
Person A	I-9	S-1	F-2	J-27
Person B	I-9	N-10	T-13	J-7
Person C	E-15	S-3	T-7	P-1

Figure 5 Cognitive breakdown of Helium-3 team

Figure 5 outlines the cognitive style of each team member – the four MBTI dimensions – introversion/extraversion, sensing/intuition, thinking/feeling, and judging/perceiving. The numbers after each dimension indicate the degree of certainty on a scale of one to thirty. It does not indicate the degree. For example, I-30 would not imply "more introverted" than I-15, but rather "more certain of introversion." As such, dimensions with a low number indicate ambiguity, usually requiring a brief interview to verify. Almost all people with ambiguous results were verified.

The Helium-3 team, while very successful in its research and presentation, had some internal issues. Person C was both extraverted and perceiving, which is the cognitive opposite of persons A and B. While disparate cognitive styles can be healthy, a single person differing on two dimensions from the rest of the team, particularly these two dimensions, does not historically end well.

In this case, person C was effectively removed from the team. Even prior to this removal it was clear that person B was the leader of the group, although person A did not hesitate to take the initiative when necessary.

4.2 International Cooperation

As space technology continues to evolve, so does the international scene. More importantly, as national space aspirations change, the dynamics of potential cooperation and competition vary. With more international interest in lunar missions since the Apollo era, both the chances of cooperation and competition in space are rising.

As illustrated by the Helium 3 team, a strong effort toward fusion power is necessary to meet increasing energy demands. This problem has no regard for national borders, and provides a useful case study on how an international effort to create a sustainable world energy economy could perform.

Thus, the team developed an intricate understanding of international research being performed on all types of fusion, and how they compare in their attempts to overcome the numerous hurdles of energy-producing fusion. More traditional methods are also currently underway. France, for example, hopes that scaling the reactor size upward will allow the problem of "break-even" (the point where energy required to sustain the reaction equals the energy generated) to be solved by a brute force methodology. Japan is trying more innovative methods, but currently suffers from an underpowered laser, which is a critical component in their methodology.

The United States as a whole has comparatively little work underway, but even its skeptical Department of Energy is researching the deuterium/tritium possibility. Hopes for He-3/deuterium research, found largely within space research circles, have no credibility at the DoE. The only such research is being funded by NASA so a single professor and four graduate students at the University of Wisconsin can explore this possibility.

The scientific and technological hurdles outlined by this team appear much bigger than what was portrayed by the Helium-3 team, which drew heavily on the University of Wisconsin research. This team demonstrated the extreme difficulty of creating any fusion reaction; trying to use He-3 makes the situation even more daunting. This is emphasized by the fact that the leading design concept for a He-3 reaction does not take into account some limiting factors from plasma dynamics.

What remains are two distinct camps on fusion power. The first is the deuterium/tritium camp, focused on Earth applications since it is possible (probability remains an open question) that such technology will be available before oil reserves run out. The second camp is focused on Helium-3 technology which cannot effectively occur before 2050. Nonetheless, the temptations of high efficiency and locally available fuels will continue to drive He-3 research – and such technology would drastically alter our spaceflight capabilities.

MBTI Data for Group:		Cooperation		
Person A	E-18	S-7	T-13	P-2
Person B	I-9	N-8	T-25	P-9
Person C	I-3	N-15	T-16	P-13

Figure 6 Cognitive breakdown of International Cooperation team

This team is exclusively comprised of thinking and perceiving types, and is predominantly introverted and intuitive. Person A is both extraverted and sensing, differing from both persons B and C. It is interesting to note that this team was the opposite of the He-3 team in the J/P dimension, possibly explaining the divergent conclusions of the two teams.

4.3 Management Perspective on Fusion Power

From the 2004-2005 work, it was obvious that Helium-3 was an important resource that could justify placing a significant, permanent, manned presence on the lunar surface. Despite the known difficulties of fusion power, it appeared that Helium-3 was the key to solving Earth energy problem. This is the type of motivator necessary for an extensive space program – not science or exploration, but a gold rush atmosphere driven by commerce. Combining economic reasons with the critical importance of energy security (somewhat akin to the political security concerns of the Cold War), He-3 was treated as a nearly pivotal focus of the space program.

With this outlook already embedded into the nature of the assignment, it was only natural for this year's He-3 team to respond in kind. It should be noted that they did disagree with last year's work in an important regard – that He-3 reactions are not the highest energy reactions possible as previously claimed. They are, however, the most efficient, and create no radioactive byproducts whatsoever.

The results from the International Cooperation team were most surprising. This team operated largely independently and it was not in their original assignment to provide a counterpoint to He-3 fusion reactors. The quality and depth of their work was impressive and showed the inherent complexities of cooperation between the disparate programs from around the world.

This is not to say that the Helium-3 team's work is of lesser quality. They were aware of the difficulties of fusion reactions, and the differences between each nation's research. There is actually negligible discrepancy between the facts reported by both teams. How then could such different conclusions could be reached?

The answer lies in the emphasis each placed on science versus politics. The Helium-3 team discounted the difficulties between the DoE and NASA as institutional in nature, following the all-too-common "Not-Invented-Here" syndrome. The cooperation team demonstrated that while there were undoubtedly institutional and political factors at work, the differences between the deuterium/tritium (DoE) and the deuterium/He-3 (NASA) camps have their origins in technical discrepancies.

Still, success with deuterium/tritium will bring the technology closer to achieving deuterium/He-3. While He-3 may never have Earth applications, its capabilities for space commerce and exploration are significant. The question remaining is how to make effective policy for both Earth and space amidst the technical uncertainties, given the limited resources and technical expertise available.

4.4 Lunar Energy Sustainability

Long duration habitation on the lunar surface requires a substantial amount of electrical power. These requirements quickly overwhelm the practical limits of solar power, leaving only fission reactors. Thus, in an effort to create a sustainable life support system, energy sustainability has been sacrificed. Can a sustainable energy source be reached?

The options for sustainability quickly limit themselves back to solar since the Moon is geologically inert, fusion power is unproven, and any hydrogen found on the surface will be in the form of water (thus requiring more power for extraction than could be harnessed). However, the lunar regolith possesses the necessary elements for making solar panels.

Provided that there is an initial source of power, automated systems already being used for vacuum pyrolysis (harvesting of oxygen, Helium-3, et cetera) can also extract silicon, aluminum, magnesium, and iron – all the necessary ingredients to create a solar panel. Tests with simulated lunar regolith have been successful at creating solar panels, albeit of very low efficiency. Given the simplicity of their construction, solar panels would be in production continuously, eventually providing more power than the original source.

More advanced concepts involve creating additional robots from the lunar regolith itself as the necessary power became available. These robots would in turn create additional solar panels. This concept would allow for exponential growth whereas the previous model, which used a fixed number of robots, would be a linear growth model.

Self-replicating robots, while an interesting theory, has not been demonstrated, and the complexities inherent with replication would prohibit its space applications in the near term. Therefore, a linear growth model is most practical, with the occasional additional robot sent from Earth to supplement the rate of solar panel construction.

MBTI Data for Group:		Energy Sustainability		
Person A	E-11	S-9	T-3	P-9
Person B	E-4	N-15	F-2	P-30
Person C	I-3	N-7	T-1	P-19

Figure 7 Cognitive breakdown of Energy Sustainability team

The energy sustainability team was entirely perceiving, but varied on all other dimensions. However, there is no single person different in two or more dimensions from the other team members. These distributed characteristics minimized both the potential for an obvious leader and for any one person to be kicked from the team due to incompatibilities.

4.5 Management Perspective on Lunar Operations

The original rationale for a large permanent presence on the lunar surface, Helium-3, has been debunked. Even ignoring the technical hurdles, the economics of using He-3 for Earth are questionable at best with deuterium and tritium readily available. Using He-3 for space applications, while appealing, is not in and of itself a sufficient rationale. Creating a large space program to support a large space program is, at best, circular reasoning. If there were a different objective, the Moon could serve as a means to an end, but He-3 is not an end unto itself.

Depending on how Earth's energy infrastructure adapts, the Moon has other resources that could come into play. For instance, if fuel cell technology became more prevalent, then platinum reserves on Earth could easily be consumed, since such metals are a key component in fuel cells. Platinum has been detected on the lunar surface in significant quantities, and given a high enough demand, it could be a sufficient rationale for an extensive mining operation.

Regardless of whether a base's initial power source is nuclear or solar, it would be prudent for in-situ production of solar arrays to commence immediately. A robust and diverse power system can be invaluable from an operational perspective, and provided enough time, the Moon could begin to export solar panels.

Manned lunar presence is required for science, testing, and training for future Mars missions, as well as for maintenance of whatever mining or harvesting operation is underway. Given the large requirements of any life support system, there will be a push to keep crew sizes to a minimum. There will also be a push to maximize the time spent on the lunar surface, so new equipment and logistics can be sent instead of replacement personnel sizes in the dozens, loosely proposed by previous projects, have not yet been justified.

There will also be a push in robotic automation of the mining operation since man-hours will be a precious commodity. Closed loop life support, including the possibility of agriculture, would allow more equipment to be sent from Earth since not as much logistical re-supply would be necessary. Eventually a self-sustaining base (or nearly so) is achievable, but the difficulty of such an operation is directly proportional to the size of the population (at least in the time line being considered).

Resources on the Moon can be applied to other space infrastructure, including oxygen (rocket propellant, life support), aluminum and titanium metals (structure), et cetera. Like Helium-3, however, this would be a means to an end, not an end unto itself.

4.6 Breakthrough Team

The work of the breakthrough team this year met substantial increase in survey respondents for the existing panels, as well as the creation of two additional panels of space enthusiasts and middle school teachers. In total, this provided over 120 people evaluating the significance and likelihood of twenty breakthrough technologies. This represents a large enough data set to determine the general trends behind technologies and create individual scenarios combining their use.

The different panels of expertise (ranging from WPI students and alumni, to enthusiasts and educators, and to experts at NIAC) allow comparisons on whether data from more easily accessible demographics (students) correlate to more difficult demographics (experts). When combined with historical precedent on how different demographics have predicted technology growth, an assessment of the future can be completed. This process is known as a Delphi study.

The survey of technologies is known as Round 1 of a Delphi study. Round 2 is the survey of scenarios. Until recently, the various Breakthrough teams have been stuck in the logistics of gathering Round 1 data, preventing any progress on Round 2. Since respondents to Round 2 must also have responded to Round 1, the long timeline of the projects have allowed some of the contacts to go stale.

However, a recently strong push in Round 1 respondents still permits a sizable panel for Round 2. As such, six scenarios were created based on various parameters: technology importance, lunar focus, Mars focus, militarism, science, and colonization respectively. These scenarios are already being distributed to current students and to additional panels during a summer IQP project, the latest in the breakthrough project series.

MBTI Data for Group:	Breakthrough

Person A	I-11	S-5	T-27	J-24
Person B	I-26	S-14	T-15	J-20
Person C	E-5	S-12	F-15	P-16

Figure 8 Cognitive breakdown of Breakthrough team

The team dynamics of the breakthrough team were complicated by the scheduling of the various team members. Persons B and C operated over the summer and into the beggining of this academic year, bridging the gap between last year's projects and the current ones. Person A started later during the academic year on a more regular schedule. This staggered operation effectively made two teams – the first comprising of Persons B and C, and the second team of Person A and Ellery Harrington from the management team.

Cognitive styles play significant roles in three person teams, but since this was not the reality of the breakthrough group, and as such team dynamics are difficult to assess.

4.7 NASA Institute for Advanced Concepts Team

Many of the technologies on the survey have been considered by NIAC at one point or another. Hence, the Initiative has been able to receive the enthusiastic support of the NIAC director, Dr. Cassanova. Since NIAC's primary function is to support promising studies of technology, and not do the studies themselves, NIAC found it appropriate to give WPI a list of the contact information for the Principal Investigators of about twenty relevant studies.

This new panel comprises the true experts of the breakthrough technologies – they are the ones, after all, working on them. It was predicted that this group would have a greater enthusiasm for the more radical concepts. Given the importance of such a panel, a dedicated team of students was necessary to carry out the logistics of the survey.

Some lessons had been learned since the release of the original technology survey a year prior. Some technologies on the original survey actually violated the laws of physics. Since there were other technologies that warranted being on the list, it was only wise to replace the impossible technologies with ones that warrant evaluation. However, changing the specific technologies has had only minor impact in the analysis, since the new technologies replace the function of the original (i.e. ram accelerator replaced by mass driver).

Due to difficulties with the web-based survey system early in the year it was decided that the NIAC responses were too valuable to be lost to computer error. Therefore, the results were collected manually using email and hard copies. Unfortunately, this also meant that the NIAC team did not have the centralized database of the web system nor were they able to immediately take advantage of the analysis tools.

The results were later entered into the database manually so the cross tables and histograms could be generated. However, the lack of a centralized storage had left some of the respondents unaccounted for, preventing their input from being included in the analysis. This is especially disappointing since the NIAC panel is quite small, making the loss of even a single response significant. It is one matter to get a low response rate from WPI alumni, since one can simply increase the pool size of alumni contacted in order to reach the desired number of respondents. However, this is not possible with the NIAC population, which is inherently small, and there no additional people to contact to get the desired number.

MBTI Data for Group:		NIAC		
Person A	E-9	S-4	T-7	P-13
Person B	I-15	N-5	F-1	P-19
Person C	E-9	N-4	T-14	J-5

Figure 9 Cognitive breakdown of NIAC team

Person B possessed both introverted and feeling qualities, at odds with with the other team members. This person left the team shortly after formation for another project, outside the space policy projects. At this point persons A and C had extraverted and thinking qualities in common. Person A quickly became the dominant member of the team, with Person C unwilling to proceed on sections without the constant presence of Person A. This was extremely problematic when Person A became unavailable due to job commitments, greatly minimizing the work completed by Person C at the end of the project.

4.8 Management Perspective on Technology Breakthroughs

The combined efforts of the numerous breakthrough teams, the team dedicated to the NIAC respondents, and the data collection and analysis system by Ellery Harrington resulted in a quite impressive data set. Round 1 of the Delphi Study is effectively complete, and Round 2 scenarios are already being fielded to WPI students before submission to NIAC.

Correlation between survey results and cognitive type, available for all the WPI alumni respondents and most of the surveyed students, must still be performed on the larger data set; such analysis currently only exists for the respondents from the 2004-2005 academic year. It is hoped that predictions can be made on the cognitive style of each of the NIAC respondents, and to then have them actually complete the MBTI, in order to compare the results to the predictions.

It is natural for a technology assessment to have recommendations or predictions on what the most promising new ideas are to take spaceflight to 2050. Such results are not yet available – the Delphi study requires a completed Round 2 to be effective. One must remain cautious to prevent personal biases and promising Round 1 results from influencing the remainder of the study.

4.9 Space Elevator.

Consisting of a ribbon stretching from the surface of the Earth to approximately 70,000 kilometers into space (nearly a 1/5th of the way to the Moon), a space elevator has the potential to reduce the costs of getting payload to orbit by at least two orders of magnitude. Engineering efforts are underway to work out all of the operational logistics of such a concept, and even NASA, through the NASA Institute for Advanced Concepts (NIAC) has entertained the possibility. The potential of the space elevator is in fact so great that NASA, which prior to the NIAC studies disregarded the concept as science fiction, has offered a $100,000 prize as part of its Centennial Challenges program.

Aspects such as wind loads, space debris, lighting, power sources, and the mere logistics of building a ribbon almost twice as long as the circumference of the Earth, appear daunting at first glance. Yet the space elevator team has demonstrated that these obstacles can be overcome. What is more unknown is the material of the ribbon itself.

The key difficulty, of course, is the development of the material that the ribbon will be made out of: carbon nanotubes. This material has the theoretical potential to be the strongest material in the world, by far. This technology has seen steady research and development since its applications extend far beyond the space elevator, particularly into nanoelectronics and superconductors. Testing the strongest materials in the world has some interesting logistical challenges (such as, what materials to build the test apparatus of), and the development has not been as rapid as NIAC reports optimistically suggested. Nevertheless, work is underway by many different organizations, each tackling the problem from their own perspective. The chances of discovering a breakthrough are significant, although predicting when it would occur is most challenging.

MBTI Data for Group:		Space Elevator		
Person A	I-15	N-1	T-6	J-13
Person B	E-1	N-2	T-8	J-15
Person C	E-22	N-8	T-16	J-6

Figure 10 Cognitive breakdown of Space Elevator team

The Space Elevator team's dynamics were strong, yielding solid work in a timely manner. Cognitive styles were largely similar, with only Person A standing out. However, person C tended to be the disparate member, largely because Persons A and B had already known each other prior to the project. There was no clear leader on the team; the members seemed to hold a “divide and conquer” mentality, with each person focusing on a specific area.

4.10 Atmospheric Harvesting

Low Earth Orbit is the first stable location on the journey out of Earth's gravity well. Vehicles at this point in their mission have used most of their alloted propellant, leaving comparatively little for further ventures. Having propellant stores on orbit to refuel at that point would be very valuable, expanding the possibilities of a given mission profile of fixed mass.

By far the majority of any rocket's propellant mass is oxidizer, and for high performance cryogenics this is invariably liquid oxygen. While in LEO, only a few hundred kilometers above the surface of the Earth, oxygen is tantalizingly close. The key is for a harvesting vehicle in LEO to dip into the atmosphere far enough to gather an appreciable amount of oxygen, while not burning up while reentering the atmosphere. Orbital kinetic energy will inevitably be lost in the process, but it is imperative to minimize this, since it will have to be restored after each pass in order to maintain a stable orbit, and to rendezvous with other spacecraft.

To gather enough oxidizer in a single pass is impossible; the altitude required would result in too much energy lost. The act of separating the oxygen from the predominant nitrogen and other gases is also very delicate, using various combinations of membranes. As such, the harvesting team determined that such harvesting is not possible. Combined with the possibilities of propellant resupply via mass drivers or ram accelerators, atmospheric harvesting appears at the minimum to be highly impractical.

It is the opinion of the management team that harvesting remains a possibility if conducted gradually over hundreds of orbits at more reasonable altitudes. After the completion of their report, it was also discovered that rarefied ionized hydrogen exists at altitudes less than 1000km. As such, since fuel comprises a much smaller percentage of the mass when compared to the oxidizer, it may be possible to harvest both halves of the propellant from the upper atmosphere while in orbit, further leveraging the capabilities of propellant replenishment. A team has been assigned to investigate this possibility further for the 2006-2007 academic year.

MBTI Data for Group:		Atmospheric Harvesting		
Person A	E-6	N-19	T-25	P-10
Person B	E-4	S-2	T-12	P-13
Person C	I-13	N-10	F-30	J-1

Figure 11 Cognitive breakdown of Atmospheric Harvesting team

The most noteworthy aspect of the cognitive styles of the atmospheric harvesting team members is their conflicts with the management team. Assistance and alternative methodologies were initially met with disinterest and later with more active hostility. It later became apparent that Person A's cognitive style is at direct odds with a manager's cognitive style. When combining an ENTP (Person A) and ISTP (manager), both feel threatened to the point where they feel the need to demonstrate intellectual superiority to each other.

4.11 A Case for Space Stations?

No space policy analysis would be complete without space stations. Between the Sayults, Skylab, Mir, and the International Space Station, long duration habitats have been the cornerstone of manned spaceflight for the last thirty years. The programs have met with varying degrees of success, largely dependent specificity of the station's goals.

Space Stations can serve very useful roles in tourism. While private flights are presently limited to suborbital missions, tourists have flown in Russian Soyuz spacecraft. The transit in Soyuz itself is cramped quarters at best, and is far from a pleasant experience. However, after two days in orbit, it docks with the International Space Station for over a week in microgravity with plenty of habitable volume for the tourist to enjoy. Once private spacecraft achieve orbital spaceflight, a space station of much less complexity than ISS (and placed in a better orbit) will provide an enjoyable "space hotel" destination.

Space stations can also serve as a point of operations for complex operational tasks. This can range from the refueling of other vehicles, construction of interplanetary craft, or to a satellite repair and refurbishment facility. These were all, at one point or another, part of the design for Space Station Freedom (to be later known as the ISS). However, after endless compromises, the ISS has lost most of this capability.

The third objective a space station can fulfill is that of a research outpost, a task well performed by the early Sayult and Skylab stations. This research can range from human physiology to material sciences, and from astronomical to microscopic levels. Regardless of the objective, long duration platforms are valuable if sufficient man-hours are dedicated to the experiments. Commercialization of this research could also provide a lucrative opportunities provided intellectual property rights were protected and access to the facilities was of minimum hassle. Again, the ISS was planned to serve in this capacity, but to date these efforts have been halfhearted and not successful.

MBTI Data for Group:		Space Station		
Person A	I-8	S-4	T-6	P-7
Person B	E-30	N-5	F-12	J-3
Person C	I-4	S-22	T-8	J-7

Figure 12 Cognitive breakdown of Space Station team

The space station team performed the same "divide and conquer" strategy that the space elevator team did, with each person focusing exclusively on a specific area. In this case each area was a potential scenario where a space station would prove viable. However, this strategy was not as effective for this team as it was for the space elevator group; in fact it led to very little communications between the team members, with Persons B and C completing their components of the project before Person A.

Persons B and C had little desire to assist in Person A's section, leaving that area of the project stranded and undeveloped until extensive work was undertaken immediately prior to the Baltimore conference. Even after the conference, there was significant work left to be done in Person A's area that was never completed to the same fidelity as the other areas.

4.12 Man-Tended Platforms

With nearly a thousand active satellites and upwards of hundreds of thousands of debris particles from the last five decades of spaceflight, Earth's orbits are in some desperate need of consolidation. Combined with the fact that virtually all spacecraft have the common requirements of power, attitude control, and communications, it is clear that significant savings in upmass could be seen if these basic resources were shared amongst multiple "satellites," payloads, et cetera.

This is the concept of a space platform, a large, empty chassis providing these basic utilities on orbit. This platform would then be filled with modules of standard size and interfaces but performing very different functions. A television module could reside next to one responsible for weather monitoring; adjacent could be a distress beacon receiver. All of these modules would share a common power system, and would not have to worry about spending propellant on station keeping, and could use a common command and control frequency.

These modules could be repaired, replaced, or upgraded as needed, following a routine servicing mission by a manned crew on a regular schedule. Spaceflight experiences during Hubble Space Telescope repairs and construction of the International Space Station have demonstrated the flexibility and capability of manned servicing missions. With a few dozen platforms, a regular maintenance schedule could be maintained, providing capabilities otherwise impractical if these few platforms were replaced with hundreds of satellites as exists today.

It would be inefficient for a short-duration manned mission to be sent every time a platform needed to be serviced. Instead, crews could spend longer times on orbit akin to the six month missions of current ISS crew members. There is precedent for this: stays aboard the Mir space station have occasionally been extended to over a year.

This may be the first way that human orbital spaceflight missions could become commercially cost effective. To date, only unmanned technology services have been commercially successful.

MBTI Data for Group:		Man-Tended		
Person A	I-15	S-8	T-17	J-16
Person B	I-30	S-9	T-25	P-1
Person C	I-6	S-22	T-9	J-10

Figure 13 Cognitive breakdown of Man-Tended team

This team shares common traits on three of the four dimensions, and is then predominantly judging. In retrospect, this distribution is poor for man tended platforms since very little research material is readily available. For sensing, such a lack of information is disorienting. Even detailed explanations by the Management team were insufficient for the team, since no citations were available beyond an ESA concept study that was two decades old. Given these limitations, it is easy for judgmental aspects to determine that the concept is unfeasible "since no one else has thought of it before."

4.13 Management Perspective on Low Earth Orbit

Combining the results of the atmospheric harvesting, space station, and man tended platform projects results in a Low Earth Orbit environment far different than what we see today. This is only emphasized further by the possibilities opened by cheap access to space provided by the Space Elevator. The world could actually see the simultaneous presence of multiple occupied space stations bearing little resemblance to Mir and ISS.

These space stations would be specific in function, such as inflatable hotels for tourism such as those currently under development by Bigelow Aerospace. Skylab-like facilities could be used for specific scientific endeavors with direct commercial applications. Vehicles akin to the later Sayult stations would be invaluable in servicing the manned tended platforms. Larger facilities, complemented with structural trusses and robotic arms, would serve as propellant processing and storage facilities that the atmospheric harvesting vehicles would transfer their collected gases to; these stations are also natural candidates for the construction sites for lunar and interplanetary missions.

With the space elevator in place, large batches of solid rocket motors could be lofted into orbit; these motors could then be attached to larger pieces of space debris and then fired, deorbiting the hazardous material before it collides with another object and creates more debris.

Smaller debris would require more ingenious solutions, but nevertheless those solutions could find their way to orbit upon the elevator.

Even with cheap access to orbit, the manifest to board the space elevator would undoubtedly be booked to capacity. Infrastructure for in-orbit propellant harvesting and processing (no doubt a complex operation) could require ten elevator loads. However, over the next few years of elevator operation, that infrastructure could provide enough propellant to supply missions equivalent to hundreds of elevator cars, easily paying for itself.

4.14 DoSpace

An important aspect of any space related venture is outreach and public education. Given the current environment, the public has little awareness of the nature and implications of space activities. This interest is slowly growing with the "epic" adventures of the Mars missions and the excitement surrounding private space ventures such as the Ansari X-Prize.

China has offered its ambitious plans, and ambiguous analogies are being made to the original Space Race between the United States and the Soviet Union. Will China serve as a catalyst for America's space program? Either way, NASA has announced the return to the Moon and on to Mars, and despite being a slow government program, it has been enough to get some space enthusiasts (this author included) excited about the future prospects of a career in a vibrant space industry.

Public awareness is achieved by doing things worthy of the public's attention: expanding the envelope, returning after catastrophes, et cetera. No outreach program can replace an exciting space portfolio. An outreach program can capitalize on it though;.increasing the public's knowledge about the missions, or by inspiring schoolchildren so that they pursue more advanced careers. whatever the field may be.The Initiative's DoSpace project goes to several Worcester area schools in this effort in order to show the beginnings of what will hopefully become a renaissance in spaceflight. Meetings are held with Future Scientists and Engineer clubs, physics classes, after school programs, and other appropriate venues over the course of several weeks, bringing in presentations from the rest of the space projects along the way. Demonstrating that such far-fetched concepts such as the space elevator obey the laws of physics boggles the mind (especially of the teachers), allowing the imagination to run wild while still being grounded in reality.

The DoSpace project to date has been well received and participating in it will be an integral component of all future Space Policy Initiative projects. Next year we hope to involve clubs from several local high schools in playing the Moon Race game created by last year's project team.

MBTI Data for Group:		Do Space		
Person A	E-30	N-11	T-4	J-22
Person B	I-7	N-4	T-10	J-5
Person C	I-15	S-12	T-20	J-11

Figure 14 Cognitive breakdown of DoSpace team

The DoSpace team's original objective was to look at what the other teams were doing and determine their applicability to Mars. This was felt to be important since the current NASA plans indicate Mars missions beggining circa 2035 – well within the timeline of the Space Policy Initiative. While it was a good project focus in theory, in practice it was far too broad to be realistic. As such, Person A requested to refocus to the DoSpace concept, and became the leader of the team.

The choice of leadership is obvious given the MBTI data, with Person A being the only one that was extraverted. Since the DoSpace project is very results-driven with interactions outside of the WPI community, the thinking and judgmental characteristics of all the team members were most valuable. It is mere coincidence that the cognitive styles of the team lended themselves so well to this particular application.

5. Conclusions

The management team was charged with the responsibility of creating a better environment for communication between the various teams. Several distinct efforts were made to accomplish this: an inter-group communication system, a public website for finished works to be showcased, coordination of large meetings and conferences to encourage the exchange of ideas, and working with individual teams to help them meet their ultimate goals.

Individual meetings and direct assistance of teams were met with a great deal of success. The software developed to support the breakthrough study will be invaluable to future teams, making meaningful and interesting analyses possible. The inter-group communication system, however, was not utilized by the teams, indicating that people would much rather use their own communication methods than use an official one that's “monitored.” The topic of successfully monitoring and analyzing inter-team communication remains an open issue.

The public website saw significant delays, making its degree of success unknown since it has not yet been put to the test. There are significant outside interests in the work from the NASA Institute for Advanced Concepts as well as space enthusiast circles, so once ready for public unveiling, the website will be of value to at least these organizations. Overall, the Management team achieved more of their goals than not, and succeeded in maintaining the possibility of a high level meta-analysis.

5.1 Future Work

Communication has been a crucial part of this project, and for an undertaking as large as the Space Policy Initiative, the issue of effective communication still needs to be addressed. Next year will see teams introduced to other teams with very similar projects. They will be encouraged to work together at the beginning, rather than forcing large meetings in the course of the project, and then hoping that teams would interact on their own accord. With similar teams working closely together, ideas will be better shared across all of the project groups. If this is the case, large meetings should be easier to manage if the team members feel that they have a duty to the other projects.

In initiating teams for next year, one member on each team will be assigned a "management" or "representative" role. It will be their job to facilitate the exchange of ideas between their group and the others as there will be no official "management group" as was present this year. This is primarily because there is no clear set of space enthusiasts assigned to the IQP. In addition, another member of each team will be assigned a Do-Space role. Their job will be to take part in the Do-Space program that was established this year by arranging curriculums and giving presentations at Massachusetts high schools. The third member of each team will be responsible for keeping the group's advisor informed.

The public portal has basic functionality and plans for an improved system have been documented. This plan takes into account the numerous problems that arose during the development of the current system. As such, it should be possible to create a new website which will fully meets the present and future needs of the initiative. With what was learned from the 2005-2006 projects, and the changes that were made to the group formation and communication processes, the Management team hopes that future projects will have the potential for greater success when working more closely with each other.

Appendix A - Glossary

Blog - a web-based publication consisting primarily of periodic articles (normally in reverse chronological order)…

Carbon nanotubes – high strength carbon configured as a tube on a nano level so that its wall thickness is that of only one or two atoms. Theoretically capable of extreme tensile loading, it plays an integral role in the space elevator. It also shows promise as a superconductor, medical applications, and in the continued miniaturization of electronics.

Content Management System (CMS) - A content management system is frequently a web application used for managing websites and web content, though in many cases, content management systems require special client software for editing and constructing articles.

Deuterium – An isotope of hydrogen containing a neutron. Used as a fuel for fusion reactions in conjunction with tritium or Helium-3. Is present in the oceans as heavy water. Concentrations indicate one deuterium atom is present for every 6400 hydrogen atoms; a small percentage to be sure, but a harvestable and abundant quantity nonetheless.

JavaScript - A scripting programming language based on the concept of prototypes. The language is best known for its use in websites. One major use of web-based JavaScript is to write functions that are not possible in HTML alone.

Helium-3 – an isotope of Helium that can be used in fusion reactors. Is theoretically capable of the highest electrical conversion efficiency of any fusion reaction. Found in significant, dispersed quantities within the lunar regolith.

NIAC – NASA Institute for Advanced Concepts. Created by NASA to promote innovative thinking for new technologies that NASA could benefit from over the next few decades. Independent from NASA to ensure conventional wisdom does not discourage new ideas.

Open Source Software - Free computer software available with its source code and under an open source license to study, change, and improve its design.

PHP - a scripted programming language that can be used to create websites.[iii]

Plugin - Tools to extend the functionality of Wordpress. The core of Wordpress is designed to be lean, to maximize flexibility and minimize code bloat. Plugins offer custom functions and features so that each user can tailor their site to their specific needs.

Theme - WordPress Themes can provide much more control over the look and presentation of the material on your website. A WordPress Theme is a collection of files that work together to produce a graphical interface with an underlying unifying design for a weblog. These files are called template files. A theme modifies the way the site is displayed, without modifying the underlying software.

Tritium – An isotope of Hydrogen containing two neutrons. A fuel for fusion reactors in junction with deuterium. While naturally occurring in the atmosphere, these quantities are extremely small. As such, the primary source of tritium is as a byproduct from nuclear fusion reactors.

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[i] Tim Climis, Amanda Learned, and Damon Bussey, "Forecast of Space Technological Breakthroughs." diss., Worcester Polytechnic Institute, 2005. 1-2.

[ii] Hinckley V. Ryan and Christopher Sciarpelleti, "Moon Race: The Game." diss., Worcester Polytechnic Institute, 2005. 2.