Bringing the Cratersville Vision Down to Earth:

The Plan for a Simulated Lunar Base Architectural Contest

Submitted 3/12/13 in partial completion of the requirements for a BS degree from WPI

By

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I) Abstract

The consistent decline of American STEM's scores on state achievement tests is a troubling occurrence. Furthermore, one of the best science education assets – professional science exhibits suitable for a class field trip, struggle (at least in this area) to attract enough viewers to cover their break even costs- and keep the door open. The cost of transportation is rising and the number of schools sending classes has declined. Accordingly, our emphasis on expanding into cyberspace and pooling visual assets from several cooperating sites was appealing to the exhibit executives. Short of setting up their own bus service, this seemed to be the best way to remedy both the issue of their competing for a dwindling pool of visitors with fewer resources to improve their collections.

In this model the students go to the closest part of the network (cheapest class field trip) and from there have visual access to the whole cooperating set of facilities as if they were in mission control of that facility and communicating with other mission controls. They can go visit the other elements of the system with their parents or private groups as individuals later on. For example if they were at mission control Earth (Framingham) and communicated with other students in Mission control at the south pole lunar

base and mission control of the Phobos base orbiting Mars, they might decide they want to visit the moon and Mars, (in Worcester and Boston) respectively some weekend.

Hence, this project proposes a radically new science exhibit concept centered on a lunar base circa 2069. It would be part of a whole space infrastructure circa 2069 complete with space stations and fuel depots and hotels in space as well as bases in several places on the moon and at least one place on Mars. This exhibit will be linked with the city of Worcester's science curriculum, and the new base will be designed to draw upon and share the visual assets of other exhibits, which it can access for a nominal fee.

This project began as an effort to create an organization capable of running an architectural contest and is ending up as the beginning of an exhibit collaborative that can undertake major projects such as the renovation of the basement of the Worcester Auditorium in to a new hub of the proposed system. In the meantime, the Ecotarium will take the lead in the lunar base exhibit development process and serve as the hub of the system until their space available is outgrown and something like the space available in the Auditorium is needed.

There contest has taken on larger implications but in addition to positioning WPI and its exhibit partners to lead the region to the next generation of science exhibits, the problems that prevented the contest from being run this year have been addressed. It can and will be run next academic year, starting in September, if there is sufficient interest on the part of the architectural community to justify the effort. SHIFTboston seems confident that there will be.

If so, the efforts of our own team and those we managed that produced the program will be responsible for a major event, the next contest, sponsored by SHIFTboston and AIAA NEC. It will start in September 2013. Material in this report will guide future teams to build on the life sciences portion of the spiral curriculum, run the actual contest, and plan future similar contests, the next one likely to be themed on a mars base and how it would be different from a lunar base. In addition, ground work for the recruitment of contest participants via a contest website is well underway, though not yet completed.

II. Introduction

A) Mission and issue

The importance of teaching science well cannot be overstated. In our view science education should involve hands on activities in the classroom capped off with a field trip to

an exhibit that is integrated with the theme line of the curriculum and stimulates the imagination while continuing to be hands-on problem solving. The purpose of this project is to run an architectural design contest to get ideas for just solving such an exhibit for New England and especially the Central Mass area, ideally to be located in Worcester Mass. The sponsors of the project are SHIFTboston, an organization that runs architectural contests, and the AIAA NEC which is the professional organization interested in Aerospace and which is supporting 5th and 6th grade curriculum development project in Worcester, MA.

The theme of the curriculum is the challenge of living and working on the moon, specifically building a lunar base circa 2069 out of materials 90% of which are already to be found in the lunar regolith. This theme was selected because a local team entered the 2010 SHIFTboston lunar base design contest and tied for first on technical feasibility and elegance. Team Goddard made the Cratersville design capable of supporting itself with exports and feeding itself, thus achieving a high level of self sufficiency. However, this is a second generation lunar base design. There are certain basic infrastructure requirements to be met by a first generation lunar base that would probably not be made out of local materials.

None the less, whether it is ever built on the moon, Cratersville can be the basis for a very engaging science exhibit which can be used to teach 5th and 6th grade concepts ranging from plant biology and ecological balance to the solar system, matter, forces, energy, electricity, light, motion. The contest focused on what the base would look like from the outside. This one will focus on what it would be like to be inside the futuristic habitat in an alien environment solving everyday problems, but most of the same raw materials are present.

According to SHIFTboston the contest cannot be announced until the technical specification of “program” is written, a location is specified and described, prize money of at

least $1000 is committed by a sponsor and a way is devised to recruit the technical students that the architects would need to team up with to carry out this interdisciplinary project is set up so they can be contacted and informed of the contest at least 3 months before it starts, tentatively on September 2013.

Thus the goal of this project was to meet those requirements and allow the contest to be announced this semester for a start in the fall. It was important to us that the college students entering a contest of this type are able to get academic credit, so the arrangements have to be worked out before they go home for the summer. That means the announcement has to be now and needs to take the form of a web page to which people can be directed.

This document is a progress report of how close we got to that goal and an assessment of whether the proposed contest can launch on schedule. It also a report of what happened because the attempt was made to be ready by this date. In brief, we positioned WPI, the New England Ecotarium, the McAuliffe Center in Framingham MA and the Tower Hill Botanical Garden to team up and seek a NASA grant for a space exhibit is the $100,000 to $1,000,000 dollar range, with a deadline of April 9. Without our groundwork setting up the contest, it would not have been possible to consider seeking a million dollar grant for this purpose. However the Ecotarium wants to host a small exhibit in the range of 2500 square feet near its planetarium. The building we had in mind for the contest has a basement of 37,000 square feet to develop. How to start with a pilot project at the Ecotarium and end up with a world class exhibit in a renovated Worcester Auditorium is not clear. However, the architectural contest will go forward as planned, with a few tweaks taking into account the plan to start small and try it outgrow the Ecotarium in a few years.

NASA will be asked for money to work up detailed architectural drawings for the Auditorium based on the best student concept drawings, as well as build an actual exhibit in

the Ecotarium. Meanwhile steps toward creating an organization capable of carrying out the larger project will be taken, and they started at a meeting we ran at WPI in late February. There the space enhanced science education collaborative was born around a concept of what the next generation of science exhibits can be given technologically through advances in interactive media developed for the video game industry.

Our project, intended to complete an initiative to rethink the proper relationship between the colleges and public schools of Worcester and have the result be a science exhibit gift from the colleges to the city, has turned into something else. It is now one step toward something larger. The initiative as a whole involves a spiral science curriculum initiative, a whole cluster of integrated science exhibits in several places that in combination reveal the outlines of a future lunar base and probably a children's book that is science fiction but technically accurate and a good read. More supplements add a layer of complexity and depth. We want to create something that puts the normal science textbook to shame and use it to prepare students for their trip to the exhibit. Alternatively they can take it home from the exhibit to be sure that the educational goals are met.

As a secondary goal we think a trip to this exhibit will be so inspiring that it will increase the chances that a lunar base of this kind, on the scale depicted (60 people on one year deployments) will be built by the 100th anniversary of the Apollo landings. We intend for the exhibit to do some consciousness raising about what is possible, the moon as a resource rich environment, and the nature of the next energy era that will emerge by the end of the working lives of the current 10-11 year olds we are meeting as 5th and 6th graders in the curriculum project side of the initiative.

The teachers are clearly impressed by the educational potential in the lunar base theme, especially those that went to Tower Hill this year as their 6th grade field trip. Tower Hill administrators seem stunned to find that groups of 60 students at a time are coming to

the botanical garden, funded by the AIAA, to prepare for a lunar base project. The idea that NASA would help them fund a new facility is a bit disorienting, but exciting. The potential in the idea is catching on and what it needs now is the powerful imagery to be created by the proposed architectural contest.

There is plenty of evidence that science education in Massachusetts needs to be improved. According to the 2012 MCAS (Massachusetts Comprehensive Assessment System), only about 69% of students ranked proficient in science and engineering. Even though this is up from the 57% from the previous year, 69% is not an acceptable number for those ranked proficient. Unfortunately, this is the statewide number including the suburbs with strong school systems. None of the cities have more than 40% proficient in science and in some cities it is roughly half that number. As cities go, Worcester has done relatively well, but 2 of its roughly 35 public elementary schools have been taken over by the state for weak performance on the MCAS. Clearly both the state and particularly the city need to be looking for new and more powerful methods to convey science concepts. Meeting this challenge is one of the underlying reasons for the proposed Lunar Base Exhibit.

Additionally, the dream of an actual lunar base completed before 2069 is dependent on the technical ability and political will of current school children when they become adults. It is unlikely that their parents will encourage them to go into the new space industry because they probably do not consider it a growing profession. Certainly, nothing much happened except for confusion, failure, and decline at NASA during their lives. They may or may not be aware that the private sector is seriously building the kind of rockets needed to return to the moon, while NASA cannot get Congressional funding to do the same.

For the next age of discovery (in space) to get underway, more students need to be focused on STEM education with space applications. It would be helpful if a second generation lunar base was established as a springboard for this new era. However, there is

a powerful movement of professionals advocating a mission to Mars departing from Earth orbit, rather than departing from the moon. The logic of developing space stations and Mars first seems to be selfish on the part of space scientists. They know they will not live to see it if we develop infrastructure on the moon first and the most interesting science is on Mars, not on the moon. However, the economic case for developing the moon first and thus using space profits to pay for the colonization of Mars is compelling. No economic case can be made for a Mars base at this time.

The establishment of a lunar colony is much more controversial than the establishment of a Martian colony. For one thing, the main activity on the moon would be mining and the case for doing that with semiautonomous robots operated from Earth is so compelling that it is hard to justify sending many people to the moon at all, much less to live there permanently rather than on a 1 to 2 year deployment such as we now do when mining or pumping oil in the polar regions. However, whether it is the spacesuit industry or the robotics industry that becomes the growth area in lunar development, there will be lots of technical jobs emerging in this new industry for those who see it coming and prepare themselves accordingly. We think this exhibit will give the region, the city, and many local people an edge in seeing the possibilities in this field.

While there will be jobs for Aerospace engineers, especially with 26% of the current pool of talent in that field due to retire in 3-5 years, the development of a lunar base will require many more kinds of experts interested on space applications than aerospace engineers. Therefore, another goal of the lunar base exhibit is to demonstrate the multi-disciplinary issues involved in the economic development of the moon, an area the size of North and South America, once called the “New World”. In addition to engineering issues to confront, there are also biological issues of how to survive and chemical questions of how to purify the water and waste without taking up too much room. In short by designing a lunar

base, one is practicing the technologies that will be needed on Earth by about 150 years from now, when the coal and oil are gone and the climate has changed such that many more areas are arid or underwater. Compared to the moon, any part of the Earth will be much easier to inhabit.

All in all, the main mission of the exhibit is to inspire students of all interests into thinking of the possibility of a lunar base. By connecting the all of the basic science subjects with one theme under the same roof, the students will gain a greater understanding of the connectivity between the topics. For example, the purification of the base's water supply is a problem that biologists, engineers, and chemists can all engage in.

B) Overview of how the Mission of the Project Evolved

The mission of this IQP was and remains managing the growth and development of the lunar base science exhibit idea. Originally, we thought our job would be to manage about 20 interdisciplinary college student teams throughout the North East competing for a $1000 dollar prize. Actually there are two IQP technical groups, neither of which includes an architecture student, drawing up the technical specification documents (architectural program) for the contest. Our management IQP team was originally completely separate from the technical specification teams, but ended up becoming the authors of the biological curriculum specifications. We were able to build off the work of the last year's IQP team that was supposed to write the program to a much smaller degree than we had hoped. However, they deserve credit for negotiating a workable format in which SHIFTboston and the AIAA NEC could cooperate on a second lunar themed contest. It would still take us more than 6 months to complete the tasks we expected to find completed when we started our project. The main idea that has remained unchanged is that the

student architectural contest should remain centered on artwork depicting the basement of the Worcester Auditorium as the site of the exhibit.

The start of this project depended on the progress made by the previous IQP team. If the contest was to start in Sept they had to have recruited the architecture and technical students from the Northeastern USA. While they drafted a letter and sent it out to the engineering schools they left recruiting architecture students to Shift Boston and that organization would not budge until they wrote an architectural program for the contest. This they failed to do, writing instead a scenario for the project and a description of the curriculum devised for 5th grade in general terms, but they did not fully ground it in the state guidelines. Clearly another team would have to tackle the problem of converting the results of the prior architectural contest into the specifications worthy of being called a program for the exhibit contest.

That main accomplishment of the It was known that the previous IQP team is that they recruited two technical teams here at WPI. Originally these teams were to enter the contest, but instead we would put them to work writing the program to support the rest of the contest. Our logic was that if the technical people were used in this way architects could enter the contest without technical backup people on their own team. The guidelines for the project would already include technical requirement to produce a technically feasible lunar base inspired by the Cratersville model.

Though Furthermore, their final report made it appear as though other universities were contacted and the architectural schools were notified of the contest, in fact they got no inquiries based on the letters they sent to deans of Architecture and there was no place to go to get more information. . Hence, our project became an effort to do what we had hoped they would do. At the beginning, our IQP was intended to be managing the technical teams, both here and at the other schools, and to verify their results. Furthermore, the

details for the second half of the contest, the one where the architecture students would be involved, would be ironed out during our first two terms.

However, we greatly overestimated the amount of work the previous IQP team had successfully completed. Their main accomplishment was to negotiate with SHIFTboston the outline of a student competition that that organization felt was workable. Then of course, we had to change that immediately breaking the process into two phases for lack of technical people to build teams around the architects they were likely to recruit.

did. The previous team expended most of their time and energy on recruiting the two technical IQP teams here at WPI- and that was a big job mostly because each team required an advisor other than Professor Wilkes and only two could be found. The many other students who wanted to design something had to be turned away. . Other schools were contacted, but the premise was not explained well enough to generate teams, and last year's IQP group did not follow up with the professors teaching the design courses to establish any. Furthermore, the publicity for the second half of the contest was drafted but not distributed. No architecture schools were contacted by SHIFTboston; so the essentially the second half of the contest was not possible and we had a new mission. Not established at all.

With these changes, the nature of our IQP changed too. Instead of overseeing many teams from different colleges, there were two here at WPI. Therefore, our focus could be geared more to ensuring that the two technical teams here understood the every aspect about Cratersville vision as well as possible. Cratersville is the proposed second generation lunar base developed put forward by Team Goddard, which was headed by Professor Wilkes and architect Dan Benoit. It Cratersville was one of the winners of SHIFTboston architectural contest "technical feasibility award" and it outlined which outlined what a second generation moon base that could pay for itself and feed itself might would look like.

It was our intention that the two technical teams base the exhibit off of this design. As a result, several seminars were arranged with the members of Team Goddard. There was also discussion of the strengths and weaknesses of “Moon Capital” the base design by tom Schmidt of Sepia associates in Hong Kong that tied for first place on feasibility with Team Goddard but was also a finalist in the architectural judging based on its superior art work.

These seminars were designed to explained the nuances of Cratersville so that the exhibit could accurately portray team Goddard’s vision. The seminars went such topics as the biosphere, the lunar sling, and the reason for the South Pole location of the base among other features of the design such as construction materials and water harvesting. The little details like how the radiation shield would be 9 meters of water or regolith were explained to the teams, and their questions were answered by the experts.

Furthermore, since the technical design contest was still disconnected from the architectural design contest, there was an opportunity to improve the goals of the project. Specifically, there was room to add a life science initiative. The previous design of the exhibit heavily focused on the engineering challenges of the exhibit. The original design of the exhibit had a required “biosphere” zone, but the structure and specifics of what was to be taught here was not discussed in detail like the robot repair room or the mission control.

The omission of the life science exhibit could be a result of the lack of an established lunar life science curriculum for the Worcester Public schools designed by WPI IQP students. The 5th grade IQP team last year established versatile and challenging lunar projects that involved mostly topics in the chemistry and physics side of physical science. However, with the 6th grade curriculum IQP team failing to produce usable material again, a rough outline of what is expected was drawn up by Joe Cacaccio of the management team. This outline goes over the various curriculum standards to be covered and gives a few examples of possible in class exercises.

C) Approach

Due to the vast changes in the actual project, the approach was also changed. The reduction in the number of technical teams allowed for a more personalized and intimate relationship between the technical teams and the management team. On the other hand, because the teams were so close, the management team was also allowed to reach out and contact potential sponsors for the future contest. Finally, the creation of the life science curriculum almost necessitated as much attention as either of the other parts of the project because the vision we developed of what the life sciences could be in the contest of the lunar base theme was far more developed than what the 6th grade teacher was getting from the team assigned to work with her. In the end the Tower Hill Field trip was .integrated into the theme by our efforts and not theirs. Marc Andelman of Team Goddard gave the main presentation at Tower Hill.

For the technical teams, the activities planned were designed to inform the teams as much as possible. If there were more teams, and if they were from different schools, the aid provided by the management team would likely have been a series of documents or web videos explaining the key points the management team thought would help the most. However, the seminars with the members of Team Goddard allowed for the technical teams to become more familiar with the idea than if the project had been carried out and remained as planned. With the personal presentations, the technical teams were allowed to ask in depth questions about any aspect of Cratersville. These seminars were scheduled so that the maximum amount of team members could attend. Due to this flexibility, the only barrier between the technical teams and the vision of Cratersville was their own attendance. Unfortunately that was uneven, but Justin White an aerospace major made it his business

to represent his team at most of the meetings, and it showed that that program was technically grounded in detail and the curriculum logic was understood by them.

The reduction of the number of technical teams also meant a reduction of the amount of time needed to guide these teams. Therefore, with the extra time, the management team was allowed to look into creating a stronger foundation for the second half of the contest involving the funding, judging and awards ceremony.to start. In order to lay the foundations, more co-sponsors were needed and they needed to be interested in the educational mission of the exhibit. needed to be established. These co-sponsors were petitioned either by a representative of the management team or a formal letter to the organization.

The prior team had recruited SHIFTboston in principle but it had no money. The first co-sponsor to support the project by voting funding to the effort was AIAA New England. This was critical step because with the support of the AIAA, the case for a space theme was weak. With the writing the checks, everyone else would accept the need for a space theme to keep them happy with the biology and energy educational activities proposed. However, AIAA NEC did not have a lot of money and was not prepared to heavily support the contest. What they could do however, was request special cat 3 supplemental funding from their parent organization AIAA Region I, which covers main to northern Virginia. So the trick was to get AIAA NEC to ask AIAA region 1 for money and to make this easy we took the program teams to the YPSE conference of Region 1 where they could meet the leader ship and brief them. One of the program teams sold the head of Region 1 on the concept and he effectively preapproved a request for $1000 in prize money if AIAA NEC put up matching funds.

Knowing this deal was possible made it much easier to write the proposal to AIAA NEC and ghost write the proposal to go the region I for them. AIAA NEC also agreed to

help set up an award ceremony, arrange for the national office to pay for a distinguished lecturer, and partly fund the creation of a web site for the contest.

The second co-sponsor will probably hopefully be AIAA Region 1 which will be asked for $1500 for prize and publicity funding. . By appearing at YSPE we garnered verbal support from Ferdinand Grosvenor the President of an AIAA region 1 and learned about his ground rules and criteria for supplemental funding. Representative (Abstract for talk at YSPE at Appendix A). The next step is to actually approach the group with a proposal, similar to the one presented to AIAA New England, asking for co-sponsorship.

Finally, the addition of the life science curriculum took an extraordinary amount of time. The beginning of the project was dedicated to learning the basis of the MCAS standards and where the students had most trouble. Since the 6th grade teacher at Elm Park Public School was a first time 6th grade teacher, other sources of information were reacquired. In addition, the establishment of the biology curriculum depended on the creation of interesting in class experiments focused the lunar base theme. These experiments were created around in class biology experiments found in other school systems, like Norton Public Schools. Each experiment proposed is supported by or consistent with the Worcester Standards for life science.

III Relationships: The Seminar and Recruiting Sponsors.

Cultivating relationships with other groups was a major part of the project for the management team of the Lunar Base Exhibit Design Contest. Some of these groups were other IQP project teams and others were independent professionals and educational bodies. The success of this project depended heavily on the way other groups perceived the proposed exhibit, contest or both. Therefore much of the time during the past three

terms was dedicated to creating, maintaining, and strengthening key relationships as we tried to create an organization capable of the project of actually planning, funding and building the proposed exhibit.

A) The Technical Teams Seminar:

One of our primary tasks was informing and grounding the technical teams charged with writing the competing architectural “programs” by running a seminar with a series of speakers they were likely to find useful in their task. We also provided feedback on their writing and their dry run presentations and made sure they did present to audiences that would provide both technical and educational feedback. Part of this was making sure everyone understood the objectives and was producing something useful, even if it was not the original objective.

Our initial plan was to have the teams compete to create the better program, but this idea was scrapped shortly after starting so that we would not have to separate the teams during the seminars or whenever we met with them. Having the teams not compete with each other made doing combined presentations and seminars easier and it was soon evident that one teams had members at the seminars and the other rarely did. It was also soon clear that they had different visions of the “market” or audience for their respective exhibits. The products were diverging naturally due to philosophical differences and hearing them present back to back was enlightening about the possibilities, as we had hoped it would be. The architectural teams to follow would have to choose between then s they would be hard to combine but one could conceive of two organizations with different audiences using the same physical facility at different times. Now the teams could partially

work together with division of labor to produce a better combined product. The division of labor also made it easier for us to hold a combined presentation and do dry runs with the tech teams at the AIAA Region 1YPSE (Young Professional, Student and Educator) conference in Laurel, Maryland and SESE (Space Enriched Science Education) conferences at WPI.

The technical teams were:

‘Team Dempsey’ named after the advisor:
-James Dempsey, English Professor at WPI and an expert on the Worcester Auditorium.
-Justin White , Aerospace Engineering major
-Dillon Lankeuceu, Interactive Media and Game Design Art major
-Julian Sullivan, Interactive Media and Game Design Tech major

‘Team Moriarty’ named after the advisor :
-Brian Moriarty, Interactive Media and Game Design Professor
-Erik Scott, Aerospace Engineering major
-Inhwan Kim, Civil Engineering major
-Julian Enjamio, Mechanical Engineering major

Unfortunately for us, Julian Enjamio left the project in early October because of a last-minute IQP opportunity in New Zealand. This left Team Dempsey with 3 members while Team Moriarty only had 2. When we heard that Julian Enjamio was leaving the project we

had to decide what to do with the teams. We considered moving a member of the management team onto Moriarty's team, but we felt that 1 person would not be enough to manage the contest. We also considered merging the technical teams into 1 group of 5, with Joe and Gregory staying on the management team. However, we wanted the teams to create more than 1 approach to the exhibit and we did not want to have 2 Aerospace engineering majors arguing about what ideas to develop. We decided to keep the teams the way they were with Team Dempsey having 3 members and Team Moriarty having 2 members. Unfortunately, since Team Moriarty had 1 fewer members, and one of the members was not a native English speaker they faced some additional difficulties and wrote a much shorter program, though in some respected one with more daring ideas about the nature of science exhibits in the future.

Starting from scratch, the technical teams did not know very much about the past contest and the concepts and ideas used to build Cratersville and much of what was known was in oral tradition. Since Cratersville is crucial to this project, we needed to orient and educate the teams as to the technical vision behind the images so that they would be able to use thorough knowledge of Cratersville in their programs. On the other hand the aerospace major on team Moriarity complained that he had missed the contest her really wanted to be in and felt he could have designed a better base, so we did not want to constrain his creativity. Anything the teams failed to write would have to be written in by us so that the architects would have a program and be able to use one, the other or some composite to design the proposed facility. We ran seminars order to better teach the technical teams all of the material they might need to use in framing the contest to avoid our having to step in at the end. In this we were partially successful.

1) The weekly seminar presentations and how they affected the programs

One of the most important things that we did for the technical teams was run seminar sessions for them. At a first meeting we listed a number of possible speakers ranging from the head of SHIFTboston to The Science Education curriculum coordinator of the Worcester Public Schools and the head of the McAuliffe Center in Framingham. They wanted to hear from the key members of Team Goddard, starting with the architect.

We invited the key members of Team Goddard to give presentations for the technical teams and hearing them was helpful for us as well, as we often later help them on their projects be remembering things said in these presentations. Since the whole point of the technical phase of the contest was to create a program with the technical feasibility of Cratersville or Moon Capital, these seminars by the people who designed Cratersville were a valuable resource for the technical teams. Unfortunately, only Justin White and Professor Dempsey were able to attend all of the seminars, and therefore only Team Dempsey got the full benefit of all the seminars. This caused a noticeable difference in the detail put into the two programs- at least until they got to see each other's presentation in the run up to YPSE.

Since our own advisor was the team leader of Team Goddard, he went first and gave a general +overview with the imagery produced and covering the roles of each of the other team members as well as the kind of interaction between them. We would later use parts of

his talk to pave the way for presentations of the program groups for other audiences. At this presentation, Professor Wilkes distributed the document “Space Policy: The Case for “Cratersville”; A “Lunar Town” which was the written version of an oral presentation given at the New England Sociological Assn in November of 2010. In it he presented Cratersville as a remote controlled robotic mining camp combined with a garden village doing subsistence agriculture and a rather pleasant place to live. A workforce of 1000 included only 60 people living on the moon at one time, each on a 1 year deployment. Over time a substantial number of employees would get to spend time on the moon. This assumes a shuttle capability able to deliver and return 5 people a month for a total of 60 a year.

It soon became clear that the two teams were hearing different things form their advisors based on their special expertise, so we decided to have each formally present to the whole group, including ourselves, to help level the playing field.

a) James Dempsey: The Worcester Auditorium (mostly history and facts)

Professor Dempsey gave a presentation to everyone about the Worcester Auditorium, the history of it, and why it was a great place to hold the exhibit. The scale of the place, how it was justified and how long it took to build was all part of the story. When he was through it was clear that everyone wanted to do a tour of the building so we set that up as well with Heather Gould of the city of Worcester planning office.

b) Dan Benoit: The Contest, What a good Program looks like and the Worcester Auditorium

Dan Benoit of Team Goddard came to WPI to give a presentation about the Cratersville contest, his new job of thinking about the use of the Auditorium, and a

description of what a program needs to be. This was a pivotal moment in the project. He gave a critical review of the program used in the last SHIFTboston lunar base contest. We made sure that everyone had access to that program even though it was no longer on the SHIFTboston webpage.

In addition to seeing Dan Benoit's and Professor Dempsey's presentations, both teams visited the Worcester Auditorium to see it for themselves. Both teams used what Dan and Jim said to write extensively about how they would utilize the Worcester Auditorium's space. Team Moriarty went a step further by writing a paragraph laying out their hope for the restoration of the building and the possible other community uses for the restored auditorium.

c) Brian Moriarty: The Framingham McAuliffe Center

Professor Moriarty gave a presentation to everyone about the McAuliffe Center in Framingham. He talked about the general model for the exhibit, how students would visit, and what they would do there. Each student who visits the McAuliffe Center is assigned to a role and spends several weeks preparing and training to do a role in a spaceship during the field trip. After getting to the McAuliffe Center, each student carries out his or her job on the spaceship. Eventually an emergency happens and all the students need to carry out their roles successfully.

Team Moriarty unsurprisingly used many ideas from the Framingham McAuliffe Center in their design. Team Moriarty's program creates an experience which conveys the feeling of arriving on an actual lunar base and what you would do on it. An especially

notable part of the experience is a solar flare warning simulation which occurs near the end. The activities are individually tailored to the student's grade level. Students would probably go to this exhibit once during their middle school years. Our vision was of an annual science field trip and thus the same facility had to support a radically different experience each year. Team Dempsey adopted that model, but not Team Moriarty. They went with the proven system used by the other space exhibit in central Mass. they also seemed to feel it was important that the children know how the base was built, not just see it in its final form.

Team Dempsey on the other hand took a few concepts for being realistic from the presentation, but did not follow the general idea of the McAuliffe center. Professor Dempsey's team put less emphasis on trying to create a realistic lunar base experience for the children and instead focuses on more detailed activities at stations designed to convey concepts and an element of the base. Team Dempsey's exhibit is also intended to be a capstone (a culmination of the curriculum) for a spiral curriculum (a curriculum which repeats the thematic but gets deeper and deeper into the science). This means there is a fundamental difference in the two plans for the exhibit.

d) Bruce Mackenzie: Technology in Cratersville

Bruce Mackenzie of Team Goddard came to WPI to talk to the teams about the technology imagined for Cratersville. Unfortunately, only Justin White and Professor Dempsey were able to attend the seminar, and therefore only Team Dempsey was able to implement the very forward looking and radical technology described by Bruce as having come out of the Mars foundation and shamelessly adopted for Cratersville where

applicable. Team Dempsey's program describes the usage and operation of the lunar surface sling, an efficient way to send objects into orbit from a low gravity place, in an exhibit room. The Water Elevator, an energy efficient elevator and airlock operated by water pumps, is heavily featured in the Dempsey exhibit as a simulated way to travel between "floors" of the exhibit.

It was actually supposed to serve as an airlock, but the device in the exhibit could not really go to the surface, so they found another way to incorporate the idea. It would exist in its full glory only in cyberspace as viewed from the control room.

e) Marc Andelman: Biology, C3 and C4 photosynthesis and the Greenhouses

Marc Andelman of Team Goddard came to WPI to talk to the teams about the greenhouses required for Cratersville, and which plants would be needed where. Unfortunately, only Justin White and Professor Dempsey were able to attend the seminar session, and therefore only Team Dempsey was able to go into detail about the required plants for the greenhouse, as suggested by Marc. Team Dempsey's program mentions one of Marc's main ideas, having a cattail swamp which would be good for water filtration as well as many other potential uses outlined in the program. They also picked up on the idea that one greenhouse would be full of C4 plants that thrive in the 20% oxygen atmosphere that the people living in the base would need, though at the price of not producing food 24/7. The more ancient C3 plants would thrive far better in a more carbon dioxide rich atmosphere that would be toxic to humans, growing potatoes twice as fast and yams twice as large, but they could survive period in which the atmosphere was changed to be comfortable for humans wanting to be in this green a lush part of the base for a special

event. The greenhouse was becoming a design element and biology Major Joe Cacaccio on our team was all ears as he wondered how to work this into the 6th grade biology curriculum.

2) Overall comparison

Overall, Team Dempsey created a better developed program. A large part of this was because of the extra member. However, Team Moriarty's program still does have its own merits such as the general idea of why the Cratersville construction material (fiberglass tubes) was superior to that of Moon Capital because it was adaptable to taking over an existing lava tube or cave and avoiding a major excavation task if possible. The idea of letting the architects choose between the programs will work well as the ideas between the 2 programs are both very good and different enough to be thought provoking.

B) Key relationships with potential Sponsors

1) The AIAA at the chapter and regional level

The American Institute of Aeronautics and Astronautics is the professional society for the field of Aerospace Engineering. The AIAA was founded in 1963 by the merger of the American Rocket Society founded in 1930, and the Institute of the Aerospace Sciences founded in 1933 (AIAA).

With more than 35,000 individual members and 90 corporate members, the AIAA is the world's largest technical society dedicated to the global aerospace profession (AIAA). The AIAA is devoted to the progress of engineering and science in aviation, space, and defense (AIAA). Region 1 covers the Northeast region of the USA and is one of the largest regions in terms of membership, rivaled only the region on the West Coast. It also covers the area of Washington DC where the national office is and the is a major cluster of activity in the Baltimore to Washington corridor where the John's Hopkins's Applied Physics lab Is located in Laurel Maryland near Goddard Space Flight Center. Region 1 is usually attentive to the needs of AIAA Students chapters and runs at least one and often two conferences by and for the students, as well as the rather unique YPSE conference, which it innovated and only happens in one or two parts of the country.

We decided that this combination conference and contest would draw the best and brightest AIAA student members in the region, and it would be a good place to announce the contest for next year and get feedback on the technical programs from aspiring experts in the field. We also knew that national office administrators would be present and the Region 1 leadership. Thus it was an excellent time and place to get some feedback on the possibility of funding for this conference similar to what Region 1 offered for the one in 2010, which was about $1000 in prize money and $500 for other

expenses. We offered to run a whole session at YPSE, two presentations on the programs and one overview presentation. For this audience they would want to know the details of the real base we were trying to simulate and this time Professor Wilkes could not do the overview. One of us would have to do it.

Gregory presented on the concept and importance of a lunar base at the November 2nd AIAA Young Professionals, Students and Educators Conference run by Region 1 of the AIAA at the Johns Hopkins Applied Physics Lab. Of the 76 papers, ours was of one of the 26 undergraduate papers and 1 of only 3 about education in the whole conference. Gregory presented to set the stage for the papers by the technical "program" teams. Gregory's job in the presentation was to co-present with the technical "program" team presentations, so that they would not have to explain the purpose of the contest, show the 2010 Cratersville imagery, describe the proposed location for the exhibit, and explain why the curriculum must be allowed to restrict the exhibit, or be called upon to promote the contest.

While it did impress the dozen or so attendees in the audience, the most promising outcome of the conference was that the management team and 1 of the technical teams talked to Ferdinand Grosvenor, the AIAA region 1 chairman. Professor Wilkes was able to set up the meeting by attending the board meeting and reporting on the activities and planned activities of the

New England chapter. Ferdinand was intrigued and encouraged the New England Chapter of AIAA to request prize money from his level in the AIAA organization. He called the idea unique and considered it potentially a world class exhibit. He later called Professor Wilkes to urge him to carry through and coached him of the forms to use in making the request and who had to sign off on it. He also had some NASA based lunar experts he wanted to put in touch with us.

This was a very encouraging response and it might mean that he would be willing to serve as a judge and come to the awards ceremony. It probably also swung the funding vote at the local chapter in our direction, since there was some opposition to spend the money on outreach to architects rather than continuing education for aerospace experts.

Building on this success, we suggested to the AIAA New England Chapter Council that, since the primary audience of the proposed exhibit is students and educators at the elementary and secondary level, science educators should also be part of the judging process. We proposed a panel of judges that would include 3 judges from AIAA aerospace engineers, 2 from architecture, and 2 science educators. This proposal was approved for funding and execution by AIAA New England, after revision. The AIAA is critical to our project because the contest and the exhibits rely heavily on aerospace concepts related to living and working in space and the AIAA

needs to become more interdisciplinary to accommodate things like building a lunar base as opposed to the operation of rockets and surviving in the space environment.

SHIFTboston required that we secure money from a co-sponsor before proceeding with the contest; so we wanted the AIAA Region 1 to co-sponsor the contest with $1000 dollars for prizes and then spend at least as much from the Chapter treasury for the web page and the awards ceremony. We also requested that a distinguished lecturer, paid for by the national level, be sought to be part of the awards ceremony. As a co-sponsor for the contest, the AIAA will be able form a committee to provide technical feedback and guidance to the competing teams, of which we hope there will be 20 in Region 1.

Our YPSE abstract is appendix A, our AIAA New England proposal is appendix B, Our large AIAA Region 1 proposal is appendix C.

2) Tower Hill

Tower Hill is a botanical garden in Boylston Ma. The garden is comprised of two green houses, an orchard and expansive grounds. At the beginning of the project, Tower Hill was contacted by the previous team to

gauge interest. However, the lines of communication were not maintained at the end of the project.

At the beginning of the year, as the biology portion of the curriculum was being redesigned, Tower Hill appeared to be a great asset. It was clear from the start that the biology portion would rely heavily on plant physiology due to their importance in a lunar environment.

Plants are essential here on Earth, and would become even more valuable in space. Plants can work as a natural air and water purifier. In addition, many plants have multiple uses ranging from medicinal to structural.

However, to accurately portray the greenhouse at Cratersville, an expansive greenhouse underground would be needed. Unfortunately the grounds at the Worcester Auditorium could not be used. Not only would it stretch the staff and budget growing and maintaining the garden, but it would also be far too small. Another obstacle would be the city itself. The plants grown in the garden at the exhibit could not be eaten due to concerns about toxic waste and zoning restrictions, nor used for any application at all. Therefore the area would be dead weight and not very beneficial to the exhibit.

On the other hand, if an off campus garden worked in conjunction with the exhibit a truly astonishing experience. After the exhibit got off the ground, and a relationship strengthened with Tower Hill, it would also be entirely

reasonable that Tower Hill could be persuaded to build a greenhouse more suitable to the lunar base exhibit's needs.

The vision was that the 6th grade students would go to Tower Hill for a capstone project instead of the exhibit, or in conjunction with it. The field trip would occur at the beginning of the New Year, during Tower Hill's slow period. Hopefully, the staff at Tower Hill would rearrange the assortment of plants to give the appearance of a higher density of plants. In the beginning this will be enough. The students of the Worcester Public School system would not have seen anything similar to this before, and a high density of green plants with a variety of fruit trees would suit the purpose. As time goes on, a more accurate depiction on the lunar greenhouse would be more helpful to the connection.

In addition to an illustrative field trip, Tower Hill could also provide valuable imagery. The exhibit is required to have a control room where other parts of the base will be displayed, whether they are in the auditorium or not. By displaying these images at the control station, students could potentially complete a task of navigating the greenhouse from another level. At the very least the imagery would help the students develop a suspension of disbelief.

However, these plans would be futile without Tower Hill's support. Therefore, a preliminary trip was established to view the grounds and to kindle interest in the project. On this trip, Ann Marie Pilch, the education director at Tower Hill, was the lead tour guide. She showcased the two main

greenhouses, the connecting courtyard, and the conference rooms. The facility was well maintained and was a mist rearranging the plants for the fall and winter displays. When the relationship between the proposed auditorium project and Tower Hill came up, she became skeptical, and rightly so.

However, she was still open to the idea of the field trip this year. Mrs. Pilch was quite enthralled with the prospect of the sixth grade class coming during the slow season. In addition, she seemed more than willing to assist technicians when imagery for the base was needed. As for the future plans, she was more hesitant. The notion of doing a specialized exhibit to fit the needs of the exhibit was not appealing to her.

Her hesitation was understandable at the time. However, since the first meeting, another tour was planned for the technical teams and a 6th grade field trip. Both trips strengthened the relationship and improved Tower Hill's understanding of the potential in the project.

Overall, Tower Hill is an invaluable asset. A botanical garden of its size provides a powerful image for the students, many of who have never seen a greenhouse before. The tank you notes for the 6th graders, were full of plant and greenhouse imagery and expressed joy and amazement at having been to such a place. So, the value of having access to such a marvelous resource was not lost on the students. Some explicitly said they hoped they could go back some day and commented on still having the plants they got that day

and noted they were getting big now. The size of Tower Hill is comparable to that of the greenhouse which will be needed sustain the lunar base. We were hoping that they all would get to rearrange in their minds how they would use that kind of space, to consider what they would grow on the moon and why. This remains a future possibility but was not the class project this year.

At the beginning of the project, Ann Marie Pilch was hesitant about making any promises for the future. This was understandable at the time. For one, to create a greenhouse to our specifications would be an expensive undertaking. Furthermore, the greenhouse would contain plants the Tower Hill was not accustomed to grow. However, since the successful field trip, and the NASA grant (both explained in detail later), Tower Hill seems more open to a future relationship. Ann Marie has actually said that as part of a future capital drive her new director might be open to having a satellite site down town devoted to urban gardening.

The opportunity to both the exhibit and Tower Hill grows exponentially from the partnership. Tower Hill receives more revenue from school groups touring the facilities during their slow season. Furthermore, these trips would be less taxing and expensive than the typical field trip. A trip to NEAM costs $20/ student admission and at Tower Hill admission is $7.00. The trip also benefits the lunar base idea by giving the students a more concrete image of the size of the lunar base project.

3) 6th grade Curriculum Team

The relationship with the 6th grade curriculum team started off shaky at best. Throughout the two terms in which the two projects coincided, very little contact was made, despite several outreach attempts.

The first meeting with the 6th grade teacher left much to be desired. For one thing, the teacher was a first time 6th grade science teacher. Even though she taught many years at the 4th and 5th grade level, her familiarity of the subjects and how the students take to each science concept was shaky due to inexperience at the level. This first meeting essentially was used to bring the teacher up to speed. She was not familiar with the lunar base concept that the students were introduced to in the 5th grade. Therefore a recap of the key concepts covered by the lunar theme and what experiments were prepared was needed and she was concerned about how the order of materials would work out given the directive she had been given by the district. In effect she was supposed to hold off biology until the end of the year, too late for the WPI students assigned to work on her biology unit to help her. However, since the current 6th grade curriculum IQP team was not at the meeting they never became familiar with mission they were supposed to take on or the problem the teacher foresaw.

This was the initial problem with the relationship between our IQP and the 6th grade team. The initial meeting, which took place before the 6th grade team started their project, could have been of great use to them. It appeared that the 6th grade team never familiarized themselves with the 5th grade material already covered by the class, and the teacher was also in the dark about that. She had not discussed it with the 5th grade teacher.

This became a problem when the biology requirement of the lunar exhibit started to take shape. The sixth grade team did not seem familiar with lunar bases in general, Cratersville in particular, the concept of the spiral curriculum or how the 5th grade projects were connected to the 6th grade. As a result, the 6th grade team did not recognize the connection between the curriculum projects and the exhibit team's mission.

When this problem was first realized, steps were taken to rectify the problem. Emails were sent to the 6th grade teacher, and the students of the 6th grade IQP team to set up a meeting to clarify the misconceptions; neither responded. It was our hope that the 6th grade team would pick up where the 5th grade team left off and start to craft a biology curriculum. Meanwhile, a field trip was being set up with Tower Hill for the three 6th grade classes to visit. This trip would kick off the new biology portion of the 6th grade curriculum. While this was being planned out, the 6th grade team was expected to draw up an activity to do at Tower Hill and plan some initial experiments.

During this time, we expected a verbose discussion to occur between our two teams. However, as time progressed, and a 6th grade field trip to Tower Hill was scheduled, funded and finalized, no word from the other team was received. Eventually, Professor Wilkes and Joe Cacaccio came together and wrote a rough proposal for the 6th grade field trip. This proposal was forwarded to the 6th grade team and the 6th grade teacher.

However, the other IQP group did not seem to take the field trip seriously. They did not familiarize themselves with the proposed activity. A small crisis could have occurred if Professor Wilkes and Dr. Andelman were not there to steer the activity back in line with the lunar base theme that justified the AIAA funding for the trip.

Even after the field trip to Tower Hill, the 6th grade IQP team did not appear too involved with the lunar theme. After several more failed attempts at meeting, the relationship between the two groups was left to atrophy. As part of the exhibit IQP, Joe

Cacaccio came up with a rough description of what the in class biology portion can look like (which is explained in detail later in the report). They seem to have done better at working with the 5th grade team to run a Mars Rover Essay contest.

4) MAST

The Massachusetts Association of Science Teachers is the teacher's organization in charge of delivering the approved science curriculum across Massachusetts. The purpose of the contest is to create an exhibit to which teachers will find value in bringing their students. Due to this goal, MAST is important to our project because the input of its leadership is influential and it can bring things to the attention of many professionals in the field who are opinion leaders very efficiently. An endorsement of the goals of the contest would be useful and judges looking for technical accuracy and curriculum fit well to improve the event. If the final exhibits do not fit the curriculum and help prepare kids for the MCAS, it will fail to appeal to them.

The purpose of our MAST presentation was to try to get MAST to co-sponsor the contest. We set up the trip so we could meet them and present our vision. Gregory and Professor Wilkes wanted MAST to help judge the contest from a teacher's perspective, help promote the contest, describe what educators want from an exhibit, and give us $500 toward the prize money.

Unfortunately the president elect of MAST, Mary Liscomb, is also the head of the Framingham McAuliffe center and was offended when she saw her organization listed among the exhibits we wanted to include in our plan for cooperation but we had not yet invited them to a meeting or talked to their leaders. As she publically disowned the insensitive before her colleagues, Gregory tried to recover by saying that the slide did not imply endorsement, only the kind of relationship we hoped to have with each entity. He meant to say that we had made connections with only Tower Hill so far but she thought the slide implied more than that and she was not endorsing an idea that was new to her nor was she willing to let MAST endorse it. She used her influence to brand the effort as premature and possibly a threat to its potential partners.

While discussions were underway with the Concord NH McAuliffe-Shepard discovery Center and Greg thought that was connected to hers, she made it clear that they were completely independent and she had not heard of our plans via that channel either. What she had heard was a required from Brian Moriarty to speak to our technical specification teams. This she had declines, or so we thought. She claimed to be waiting for more information, like a business plan, to see if we were a serious startup or a pie in the sky team not worth her time and attention. .

So Gregory learned the importance of first impressions and that we need to be clearer when we talk about our plans not to imply communication

and possible endorsement before they are pro-offered. MAST decided that it would be a channel of information so that individual could participate in the judging and workshops etc, but as an organization it would take a wait and see attitude. At most they wanted to talk to us later when we were closer to being ready to start the contest, and had a clearer plan for funding – a business plan. Mary Liscomb's attitude did not change until we called a meeting to explore the possibility of NASA funding. That got her attention, as did the idea of sharing visual assets that she did not have room to create on her own premises. She really wanted to meet and explore the possibilities with Tower Hill an organization that was in no sense a competitor, but could enhance her visual experience from her newly constructed Mission Control Earth facility. The upshot of that (the SESE meeting) will be reported in a later chapter. However, at the time, the mission to MAST was a failure. The organization did not agree to co-sponsor the architectural contest.

IV) Addition of Biology

Even though the planned exhibit is intended to teach physical science and reinforce engineering principles, a greater focus on the life sciences is needed. The current state of the exhibit is based around the project created by the 5th grade team which was trying to convey concepts associated with

matter, forces, energy, light and electricity. In order for a vibrant and engaging life science addition to the exhibit, an equally close connection between the exhibit and the 6th grade projects must be created. One member of team Goddard was a botanist and water purification expert. That same attention to designing a biosphere needs to be captured by the exhibit- 40% of which would be devoted to agriculture of various kinds. This section of the architectural "program" is written by Joe Cacaccio, a biochemist, with advice from various teachers from Worcester County and Bristol county as well as direct reference to the Massachusetts science requirements these teachers work with on a daily basis.

A) Purpose and Motivation

The future of STEM education has always worried educational administrators and teachers. Every year, teachers look at the performances of students in STEM, and for a long time the trend has been that STEM performance (especially math and science) was decreasing. To offset this, Massachusetts Education Board required high school students to pass a standard test in biology (as well as the science MCAS) to obtain their diploma. Since the introduction of the test in 2008, the students deemed "proficient" in at least biology went up from 57% to 69% (Mitchell, 5). This is an increase of

about 2% per year. Although this increase is a start, the test does not encompass all areas in STEM. Rather, the students must show proficiency in one of the areas under STEM to satisfy the requirement.

However, there is also a trend in current school placing an emphasis on engineering and physical sciences. This is not a bad thing, with programs such as FIRST and lLEGO Mindstorm, the engineering disciplines are increasing their hold on the average student's interest, but at the moment it is generally the few, the future scientists and technologists, about 10% of the students that are actively engaged by these activities. The concerning fact is in the lack of novel and interesting approach to the life sciences with less description and memorization of terms and more problem solving and design.

It is understandable that there is a lack of novel life science activities. After all, the complexities of higher level biology and chemistry, the really interesting things, baffle the some of the world's greatest minds. Most of the advances in these sciences come from advances in the complex, unlike advances in robotics that makes the production of a robot cheaper; thereby making it more accessible to everyone. However, this does not mean the microbiology revolution in the life sciences should be ignored in the school system.

The lunar exhibit is a unique opportunity to display the complexities of life science without alienating or overwhelming the students. Building a habitat

on the moon requires a critical view of our own environment. In order to create a habitat on the moon, scientists have to judge what aspects of the Earth they can reasonably bring to the moon. The delicate new lunar base interior ecosystem will require a new type of engineering (prelude to terraforming a place like Mars with more natural resources). Hypothesizing what the lunar ecosystem or biosphere might be like is a great way to engage students and get them to functionalize their study of the life sciences. The goal is that the students will be able to hypothesize the lunar ecosystem as well as any scientist who is not a specialist since it is as much a matter of creative design for a given outcomes as a matter than can be proven through rigorous experimentations with sophisticated equipment. .

B) State, city and teacher requirements

Even if the lunar exhibit had a strong and multi disciplined view of the life science, no school would spend time to utilize the resource if the lessons taught did not meet an equivalent curriculum guideline or standard. Thus, the current obstacle of showing curricular relevance is to not only the biology section of the exhibit but also the entire premise of the exhibit. However, the physical science portion has a head start in this respect thanks to the contribution by last year's 5th grade curriculum development IQP team. The

6th grade team failed to deliver a biology unit to build on the 5th grade start, despite the fact that the advisors were a botanist who had worked in the NASA salad bowl project. Thus another team was recruited to try again, this time at Elm Park School working with the veteran s of the 5th grade unit themselves. However, the new project advisor is not a botanist and not committed to the lunar base thematic. Hence, her team was not making progress and the biology portion of the curriculum was still lacking the desired themes for this project at the point that the curriculum to be supported by the exhibit had to be specified. .Therefore, a proposed 6th grade guideline is needed and I drew the task of developing it for the purposes on the contest- and ended up in discussion with the 6th grade teacher at Elm Park School as a result. She has now bought into the lunar base theme as a result. .

Let me begin with a critical view of the Massachusetts state curriculum goals. The biology requirements set by the state covers a broad range of topics intended for students from 6th-8th grade. These topics range from the basic component of life to the interactions between species to form an ecosystem.

Essentially, the broad mastery of biology can be broken down into two main topics in biology, biology of life and biology of the ecosystem. In the biology of life, the students obtain knowledge of the biological systems that make up an organism. These topics range from organ systems, to the nature

of cells. In the biology of the ecosystems, students obtain a working knowledge of how the different organisms interact to form the ecosystem. Furthermore, the students will learn to recognize general trends in a habitat in expansion and decline. Both of these topics depend heavily on each other and are essential to understanding biology.

The Massachusetts framework published in 2006 gives the key points of each of these two main ideas. Standard 2-9, 14-16 involves the biology of life and 10-13, 17-18 involve the biology of the ecosystem. Some key points of these standard include; the key structures of a cell (3), identify the major functions of the cell (4), identification of the different organ systems (6), comprehend the functions of genes and pathways of inheritance (7), explaining the basics of genetic variations and environmental factors (10), understand the components of an ecosystem (13), explain the roles of producers and consumers (14) (Peyser, 51-53).

In order to gain further specificity in our curriculum, the Worcester City curriculum was also consulted. It is here that the biology can be placed in one of two places. On the one hand, in the sixth grade students' move from cellular structures and functions to cellular organization and differentiation; finally the students would finish their last term learning about the body and biological communities (Worcester, 142**)**. It is important to note that the Worcester curriculum has a heavy focus on the molecular and species side of

biology whereas the state keeps the topic broad. On the other hand, the curriculum does not go in depth about the biology of the ecosystem until 7th grade. The true meat of the 7th grade biology curriculum is centered on aspects of the ecosystem. Some topics are energy flow in the ecosystem, biodiversity and adaptation, and ecosystem interactions (Worcester, 143). Therefore, the exact placement of the biology emphasis in the spiral curriculum is variable.

On the global scale, the focus on plant biology and diversity gives the exhibit greater flexibility. If the biology section was based in the sixth grade, the focus would be on a cellular level. The specific sections covered by the exhibit would be: 06.SC.LS. 02, 06.SC.LS.06, and 06.SC.LC.15 (Worcester, 146-147). These sections place a heavy emphasis on the biology of the individual. If the spiral curriculum was to adopt biology into the 6th grade portion, then this must be their focus.

Meanwhile, the 7th grade focuses on the role of the ecosystem and specific niches. The specific sections that the exhibit will aim to cover would be: 07.SC.LC.03-07.SC.LC.09. (Worcester, 149-150) Uniquely, the 7th grade will touch upon plant biology topics. Should the biology portion be placed in the 7th grade, students will learn what constructs are necessary for an ecosystem to thrive.

Therefore a decision on what grade the biology portion of the spiral curriculum needs to be made. On the one hand, the 6th grade's focus on cellular biology and human systems can have a personal note to the exhibit. The exhibit will be able to focus on the implications of living on the moon on the human system. A capstone in this will likely unite physics and health as both play a role in how Earthly conditions are described. On the other hand, the 7th grade curriculum covers ecosystems in dept. There is a stark contrast between Earth and lunar environments, the latter being completely hostile though made up or largely the same mix of chemicals in the rocks. In order to live on the moon for an extended amount of time, the environment must be changed to make life as we know it sustainable. In doing so, the students will have to think critically of what the Earth has that is a requirement of life and what is superfluous. Further thought can go into how humanity can colonize other planets, like Mars. Along with the study of the ecosystem, the 7th grade curriculum covers plant biology. Plants will be crucial to living on the moon; they will be the main source of food, construction material, and an easy way to purify both the air and water. Along with the study of biology, the exhibit can cover chemistry in conjunction with the life science.

Overall, it is probably better to focus the biology portion of the spiral curriculum in the 7th grade. The original plan of the spiral curriculum thought up by the past team did not take into account the current curriculum of

Worcester. Even though the 6th grade curriculum would be able to integrate physics and health along with biology, the advantage of an in depth and complex understanding of the basis of ecosystem and plant biology fits better with the goal of the exhibit.

C) Current situation

At the beginning of the project, the biology section had a lot of potential. Since there was no previous relevant material, the current 6th grade curriculum development IQP group had free reign in what type of projects to develop into activities. Mrs. Puskas created more space for developing the theme when she decided to follow the Tower Hill trip with a 6 week period of science fair project development. Only in this way could she do biology at that time in the year. These projects could then be adapted to the 7th grade if the biology part was moved next year.

The reason why the sixth grade IQP is being done again this year is due to the unsatisfactory results of the past year. The ultimate result of each IQP team is to produce reusable material with a central theme around the lunar base. Each team adds a portion of the spiral curriculum by working closely with the teacher and the other IQP teams. Last year's 5th grade IQP team was a tremendous success creating several in- class projects that develop the

lunar base theme and collecting special equipment to enhance them.

However, the 6th grade team was not as productive. The difficulty lies in understanding the lunar base concept as a whole and how each part of the curriculum fits together. After the students enter high school, they are supposed to have a comprehensive understanding of the applications of each topic they learn in school and the mysteries that lie in space. The 6th grade team last year did not understand the scope of their project, and resigned to making a typical biology unit when their teacher at Flagg Street School did not express interest in it. . This unit, as well crafted as it was, did not fit into the larger project; therefore their work was not applied to the sequential year by year development like the 5th grade IQP teams' was.

Therefore, the current sixth grade team had a completely clean slate to work from this year. In addition, the sixth grade teacher was given a timely briefing of the intention of the project as a whole by Professor Wilkes and accepted it without question. Finally, Joe from the management IQP team was ready to work in conjunction with the 6th grade team to help integrate the new curriculum into the exhibit.

However, it did not take long for everything to fall apart. Despite these advantages we still found ourselves working against the grain of the curriculum. . First of all, it turned out that the Worcester curriculum coordinator planned for the students to study biology in the last quarter of the school year.

This did not fit with the project, as the 6th grade team would be finishing up their project in D term, before the biology portion of 6th grade even started in about May. In order to get around this, the teacher agreed to have the students work on their science fair projects after the Tower Hill field trip. She would guide the students into doing biology and would have a chance to encourage lunar based projects with the help of the 6th grade team. Unfortunately she gave them a choice of project subjects and few of them went with the new subject area of biology and stuck with topics related to chapters in the text already completed, like energy.

Additionally, the 6th grade IQP team was not set to start until B term, while the management team started in A term. Therefore, the 6th grade team could not become familiar with work with the management team' perspective or work as closely with them as expected. This would not have been a problem if the team was familiar with the established material of past IQP teams and the overall goal of the exhibit. However, it is clear that the 6th grade team did not take the time to become familiar with the materials produced by the 5th grade team the year before and which their students had already experienced. . Therefore, when B term came around the team struggled to get their bearings. Again, this problem could easily have been solved if the management team was contacted, and alerted to the situation.

At the time, the management team was preparing to go to an AIAA

conference in Maryland and setting up a field trip for the 6th grade to go to Tower Hill.

Since the 6th grade team did not become familiar with the lunar base material, the trip to Tower Hill was not utilized as the start of the envisioned project. It was the vision of the management team that this event would kick off the lunar base theme. However, the activity the 6th grade team was less than spectacular. In fact, their planned activities for the trip had no connection to the lunar theme at all.

At this time, Professor Wilkes and Joe came together to design a more appropriate activity. This activity did require a bit of guidance by the 6th grade team and some familiarity with the lunar base theme. However, the activity was duly ignored for some time. When the field trip came along, the 6th grade team was not ready to manage the trip. Luckily Professor Wilkes was there to help the team connect with the lunar theme by recruiting Marc Andelman to give a talk at the outset of the field trip. He oriented the 6th graders and tied into their 5th grade experience and guided the students.

After the fiasco at Tower Hill, it became clear that the 6th grade team was in trouble, being asked to support general science when they were biology majors and not being allowed to carry out their mission to develop a biology unit to build on the 5th grade units. They were turning to the text activities in desperation, and those are not very good. They would be

seriously inferior to what the 5th grade science experience had been. So, the 5th grade kits were made available to them in light and electricity with the warning that they had some lunar base activities with these same kits the year before—but there were some new activities that had been developed they had not yet seen in order to aid the 6th grade team, a meeting was set up with the 6th grade teacher and the 6th grade team. At this time, it was realized that the teacher still was not briefed by the 6th grade team of the depth of the lunar base theme. In fact, she did not know of the 5th grade project or the ultimate goal of both of these projects. She seemed to have forgotten her briefing 2 months prior. Furthermore, no supplementary guidance was given to the students by the 6th grade team after the field trip. Therefore, many of the students did not continue with the biology theme, let alone the lunar application. However, there was still hope, for the 6th grade team still had to design in class projects, and the teacher agreed to help push some students back to the lunar theme if the support was there. In order to ensure the success, Joe offered multiple times to help support the team.

Eventually it became clear that the 6th grade team would once again drop the lunar theme. However, the exhibit contest needed the biology portion of the spiral curriculum in place. Therefore, to help guide next year's team, the Tower Hill activity and some ideas for in class projects are provided in the next two sections. The in class projects are geared more towards the

7th grade curriculum. Future teams can use any of the ideas they wish, or redesign the whole project system. The hope that these example projects will give future teams something to aim towards and work with. The exhibit needs all pieces of the spiral curriculum in place in order to ensure success.

D) Tower Hill Biology activity

The following is the suggested lunar related activity for the 6th grade curriculum IQP team to be done at Tower Hill. Overall, it does not explicitly need the plants Marc Andelman had in mind for the actual lunar base (like cattails). Rather a wide range of plants are needed. In general, the students will think critically of each plant they see and what kind of secondary use the plant can have (other than producing oxygen from carbon dioxide).

The specific standards covered by the activity are:

For 6th grade:

06.SC.LS.02- describe the diversity of living things

06.SC.LS.07- recognize that cells perform the actions of life and producers of the chemicals inside the plant. These chemicals (like aloe) or fruit are results of biological processes and have a function for the plant

06.SC.LS.16- describe the different chemical, mechanical, and electrical activities in the cell and why they are important

For the 7th grade:

07.SC.LS.03- describe how organisms interact and have different functions within the ecosystem that enable the ecosystem to thrive

07.SC.LS.04- observe symbiotic relationships

07.SC.LS.05- describe role of producers and consumers

07.SC.LS.09- describe the basis of photosynthesis, how plants use light energy and carbon dioxide to produce sugars and why

The activity:

It starts by breaking up the kids into 5 teams (4 kids in each team). Each of the students will receive a topic to become a “specialist” on. The 4 topics are Water Processing, Air Exchange/Purification, Nutrition, Mis. Uses of plants, and Living Quarters/aesthetics. Each student will then pair up with the other students in the same field and go through Tower Hill Botanical Garden looking for, and learning about the different plants and how it could be applied to the topic of their specialist. Once they return to school, the groups meet back up and each specialist explains what they learned. The groups then design a greenhouse for the lunar base and the living quarters taking into account the biology of each plant.

Here is a breakdown of the goal for each topic:

Water Processing:

Plants are natural filters. The have the ability to pull sediments out of water to purify it. Plants like cattails are very good at this. It is the student's goal to come up with a way to purify the water using a mixture of these plants. Such things to consider is the nutrition of these plants (Cattails are edible) and the use of fish and other marine animals.

Air Exchange/ Purification

There are a variety of photosynthesis. Each variant has a benefit and a drawback. The types of plants chosen will need to be carefully considered and segregated according to these factors. For example, a cactus will not grow as efficiently as bamboo or cattails in the greenhouse (the where C02 and humidity is greater than they are used to). Likewise, it would be wise to have fruit trees and other perennials.

Food

As simple as it sounds. What plants are the most efficient and most yummy. Students must think out of the box for this one; although wheat and grain are staples of our diet on earth, a high volume of wheat is needed for our

everyday foods, which is impractical.

Mis.

Many pharmaceuticals are derived from plants. Simple lotions and skin care products are derived from Aloe, while many chemotherapeutic drugs come from certain trees (Of course the students won't be planting trees on the moon to make cancer drugs). It is up to the students to come up with plants that can be helpful on the moon. Again think out of the box. The fibers from a fern leaf or bamboo could be used to make gauze. Or maybe cotton for textiles (clothes, paper, towels).

Building materials are also considered here.

Fun idea, can the students come up with a way to make duct tape??

Living Quarters/Aesthetics

Flowers are nice, but are they necessary? (Sunflowers can be used to make a kind of rubber and the seeds are edible.). Many people today are allergic to pollen. The students will come up with a design of the living quarters that takes into account creature comforts, psychology, oxygen levels (how efficient the plant is at turning CO2 to O2). The plants should be from the same biomass to maximize survival (don't stick a flowering cactus with a tropical plant).

E) Some in class activity examples

These in class activities are what the 6th grade IQP team this year was supposed to produce. Each experiment has a specific question that can easily be linked to the lunar theme. Furthermore, these experiments can easily be made more or less complicated depending on how advanced the class is.

1. Adaptation Island

a. Teaches evolution, adaptation and natural selections

b. Length: 1 week, about 10 min per class

c. Description:

Students pair up and create a fictional creature. This creature can be a composite of at least 2 animals or a completely new creature. Students write an essay about the animal's habitat, behaviors, niche, eating habit, population habits. The animals are then put onto a proverbial island. Each day, there is a new catastrophe that forces the students to adapt. The creatures can modify 1 trait to survive the event if necessary. After the animal has adapted to that event, the students write a little paragraph describing how it survived and what

the consequences are (i.e. vestigial organs, speciation, etc). This lasts for about a week.

d. Optional: Students can make creatures out of clay. An island can also be made with several environments. For example: volcano, forest, beach, and mountain

e. Relation to Moon: The moon is an entirely new environment. Plants and animals (even humans!) will have to adapt and evolve. Over various generations, the animals/plant may not be identifiable as derived from those here on Earth. The activity could be changed to a moon base with established animals. Students could hypothesis what creatures would look like after adapting to UV exposure, lower gravity, sparse resources etc.

2. UV light plant growth

a. Teaches photosynthesis, UV radiation damage/mutation, dangers of light energy

b. Length: unknown

c. Description

It is well known that plants need light to survive, but on Earth much of the harmful radiation is blocked by the atmosphere. However, in space all of

the radiation is experienced unless measures are done to shield organisms. In this experiment, a control plant grown in normal daylight is compared to one grown under a spot light/desk light and a plant grown under a UV light. The last two plants should be isolated from as much natural light as possible to control other variables. As the experiment continues, the plant growing under UV light should start to die. UV light mutates DNA of organisms. The students can learn about chromosomes and replication and the type of DNA damage. Eventually the UV plant will die and the other two will survive.

d. Optional: another plant can be grown under both UV and desk light. Compare how long this one lives. Another plant could be grown by desk lamp and a UV lamp (side by side), but think of a way to shield the UV light without blocking the desk lamp light

e. Relation to moon: UV damage and other harmful radiation is a serious concern in space habitation. Our DNA is very fragile and our cells can only repair so much damage. This is why Cratersville is 1) underground and 2) has light pass through water first to absorb much of the radiation

3. Double Photovoltaic energy

a. Teaches light energy and photosynthesis

b. Length: 1 class

c. Description:

Photovoltaic cells are great way to harness energy from natural light. However, currently the cells are not wholly efficient. One way to increase yield is to couple the reaction. Scientists are working on artificial photosynthesis for an additional boost in energy. Photosynthetic bacteria are used as filters to absorb a variety of light before the light hits the solar cell to gain energy. The sugars are harvested and made into bio fuels.

For this experiment, a simple light filter of a variety of colors is placed in front of the light before shining onto a solar panel. The voltage is read and compared. The students discuss under what conditions creates the most energy output and can explore the different types of photosynthetic bacteria.

d. Relation to moon: This would be an easy way to increase fuel source, but has not been integrated into Cratersville. Students can discuss the advantage and disadvantages of filtering the light, like if there is a significant decrease in energy output.

4. Uses of plant (i.e. aloe, sage, mentha)

a. Teaches evolution and uses of a variety of chemicals. Thinking critically about other uses of plants besides food

b. Length: 1 class

c. Description

Besides edible plants on the moon, the lunar base crew needs a variety of medicinal and building supplies. It would be a lot easier to grow all of these necessities than to ship them in. Several common plants have multiple purposes. For example, Aloe is an anti-inflammatory and a skin conditioner well known for sun burn remedy. Sage is a wonderful spice but it too has anti-inflammatory and disinfectant properties. Mentha is a plant that produces menthol, a numbing agent that also feels very cold and is very useful for medicinal purposes but it is also a mint substitute. Students can grind up a variety of plant with similar effects using a mortar and pestle to release the chemical. Students then think critically of A) why the plant makes it B) what uses it can have on the moon C) How is it helpful in Cratersville

d. Relation to Moon: plants will need to be greatly versatile on the moon since space is limited. Even though they will be used to clean the water and purify the air, more uses would be appreciated.

V) Results

A) Biology and Life Science Development

Throughout this project, the responsibility for developing a life science curriculum was deferred to more appropriate groups. During A and B term the hope was that the current 6th grade IQP team would develop a life science curriculum with a central theme of the lunar base. After the team repeatedly failed to live up to the expectations, action had to be taken.

In order to maintain the spiral curriculum, the biology section of the life science focus of the exhibit had to be developed and tested. However, with the limited amount of time, testing could not be completed. On the other hand, the biology focus has been developed farther than it has been since the beginning of the Lunar Exhibit project and the promise in this approach is already evident to us and to the 6th grade science teacher. As a result of this IQP, next year's biology curriculum IQP team will have some examples of what can be done with the theme.

The lack of results could be a result of the biology team never having specific examples to use but is more likely a result of not understanding the lunar environment and the challenges of building a base in detail. There really is nothing written up about Cratersville that is detailed. It is in oral tradition and they are not asking to be oriented as the program teams were. . . The

current 6th grade team is focusing on applying last year's 5th grade IQP work. Although the teacher thinks this is a good idea, it is not what this project was looking for as a result. The expectation was that the current 6th grade IQP team would develop something similar to the 5th grade IQP work but that built upon it with a focus of biology instead of physics.

The author took the primary steps of establishing the desired product. It began with critically examining the state standards, and then compared the 6th grade and 7th grade biology curriculum. After conferring with a variety of teachers around Massachusetts, several key points of the Worcester Curriculum was highlighted because these are the areas students generally have difficulty mastering. With this in mind, several in class experiments were designed with the lunar base as a central theme. If the development of the biology curriculum was started sooner, these experiments could have been tested in class. However, due to time restraints, these experiments will remain only as examples unless another IQP team implements them.

Overall, even though the 6th grade IQP team did not produce usable material, a biology curriculum was developed that is compatible with and draws upon the lunar theme. With the help of the exhibit, students will realize the vibrant world that waits one in working with the life science to solve problems. . Furthermore, the students will realize that the possibility of life on other planets is real but requires a multi-disciplined approach. It is not all

rocket science.

B) State of Affairs and Future

Everything needs to be prepared ahead of time in order to successfully run the architectural contest. We originally hoped to run the architectural contest during our project, but too much work had to be done before we could begin the architectural contest phase to allow that to be possible. Our new primary goal became to leave the project so that it would be completely sponsored and ready to commence one year later. . While working on this, the next goal we had was to make a plan to produce the architectural program for the exhibit. Near the end of our IQP, we also began to work on the long term future goal of the project to create a network of science exhibits organizations focused on those located in Worcester. We hope that the work we have done will make a great contribution to the way science is taught to future generations of middle school students. Luckily everything is nearly in place to start the contest in September 2013.

Phase 1 of the contest has been a success and the project is ready to proceed to stage 2. Both technical teams have completed their architectural programs. While Team Dempsey's program is significantly longer and more detailed, Team Moriarty's program still offers some valuable concepts. Strong

architectural programs are the critical for the students in the architectural phase of the contest. The ability of the architectural teams to choose from both programs will help create a good final result.

We also needed a web designer to create a website we can direct students interested to and promote the contest. We were able to recruit I Alumni Eric Tapley to frame the necessary website and have given him many of the necessary materials to do so. The last thing we needed for phase 1 to be a success is for SHIFTboston to announce the architectural contest and officially start it in September. It would be helpful if another team to take our place can be recruited. . SHIFTboston refused to announce the contest before the program was written and we secured the AIAA region 1 as a co-sponsor to provide the prize money. Our efforts in getting the AIAA behind the contest were successful and therefore the contest can proceed.

The contest needs to lead to advancement in STEM education to truly be considered a success. Our plan, which the technical teams built teams built much of their programs around, was to use the large amount of space in the Worcester Auditorium's basement to build the exhibit. We thought that this would be the ideal place to hold the exhibit because it has a 37,000 sq ft of usable space, the city of Worcester is trying to find a use for the massive unused building, and it is walking distance from WPI. The downside to the Auditorium is that since it has been unused for a decade, it will require around

$50 million dollars to fully restore it and at least 5 million and probably $10 million before even the basement can be used for the exhibit. Our chances of being able to get a grant of that magnitude are very low. However, after the SESE conference the Ecotarium became extremely interested in our project and agreed to give us space in their building to place a prototype exhibit requiring 2500 Sq ft.

The Ecotarium is much smaller than the Worcester Auditorium, but it is still a great alternative location. The Ecotarium will let us use 2,500 sq ft of empty space, a planetarium with 100 seats, 3 classrooms able to hold a total of 100 people, and provide access to a TV studio with staged seating for 200 people. The great thing about the Ecotarium providing us space is that we can build part of the exhibit without a massive initial cost. Since the programs are designed to utilize the Auditorium's space, we will propose to tell the architectural teams that we recommend confining themselves to half of the Auditorium space.

We will shift the project into a pilot stage to see if the Worcester Public Schools will endorse the project and possibly change from 1 science field trip in 6th grade to 1 science field trip per year from 5th-9th grade. As part of our effort to create a network of exhibits, we hope that we can make our exhibit accessible by going to exhibits in other cities such as the McAuliffe center in Framingham, Tower Hill Botanical Garden and the Connecticut Science

Center. We hope that we can use the Ecotarium's TV studio to "visit" exhibits in other cities.

Even though the initial exhibit will be placed in the Ecotarium, we still have plans for the Worcester Auditorium when we outgrow the space in the Ecotarium. Even though we will have a good amount of space in the Ecotarium it is limited and there is no reason exhibits there cannot be linked with other at the site of the Auditorium. Since the architects will be creating designs for areas much larger than the Ecotarium can provide, the Cratersville exhibit should eventually (possibly in 5 years) move to the basement of the Auditorium. In order to lessen the burden of funding, we will split the space with Bruce Mackenzie of Team Goddard and the Mars Foundation. Some of the Auditorium would be devoted to the lunar base, some would be given to the Mars Foundation to make a Mars base exhibit (which may be created with help from another WPI run architectural contest), and all the technology that we decide would be on both bases would be in a third exhibit. After we leave the Ecotarium, we can create a new exhibit for the Ecotarium such as the observatory on the far side of the moon or even a base on Phobos. This would fit very well with their planetarium.

The future of the exhibit is still uncertain. The Ecotarium may want to keep the Cratersville exhibit and build new space for whatever does not fit in their current space. The Ecotarium might consider building its own

greenhouse for the exhibit and this might lead Tower Hill to consider new construction at their current site or a satellite location downtown. Other museums and exhibition sites might follow the Ecotarium's lead and ask for an expanded role in the network. The Concord McAuliffe center may get a new source of funding and ask to be part of the project in the future. The University of Maine might also be interested in creating an exhibit. There is no way of knowing where the exhibit will be at 5 years from now when we hope to be expanding out of the pilot phase at the Ecotarium.

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Appendix A: YSPE Abstract

The Cratersville Student Contest: Design a Simulated Lunar Base Science Exhibit

By Joseph Cacaccio and Gregory Sharp

Imagine that you are a 5th grader, ten years old, and there is a special “Space Enriched Science Education” curriculum experiment going on in your school. Thus, in your science class when you are dealing with sections on matter, motion, forces, light and sound, energy and electricity there is an activity dealing with one of the challenges of living and working on the moon. Some of these challenges include separating the metals mixed in the regolith to get building materials, figuring out how to mine water and transport the resulting ice from the bottom of a crater, and how to use the resources at hand to allow electricity to flow through the base. The solution to these problems is routed in the basic concepts the 5th grade curriculum covers.

Then as a 6th grader there is a unit that returns to this theme to examine the biological issues, focusing on greenhouse food, fibers, the biosphere and water reprocessing. These topics will examine how life on earth can be replicated on a much smaller scale to allow for a self-sufficient base on the Moon, and eventually Mars. The students will learn how the Moon base will have to modify to living conditions of the plants to allow for accelerated growth and higher yield. In addition, the students will learn how human life will change due to the different environmental factors. These topics will focus the student’s attention on the vast contrast between the conditions on Earth and those on the Moon, thereby reinforcing the ideas learned in the previous year.

The plan is to have every year lead into the next, thereby reinforcing the previous years' topics. This spiral curriculum would flow from 5th grade all the way up to the 9th grade. Therefore, a tie in facility supplementing these topics would be of great use.
The challenge of this contest is to have college students in aerospace, architecture, and other fields, team up to envision, visualize and draw up images of what this perfect field trip capstone exhibit should look like. Part of the challenge is that the audience returns annually for 5 years and gets a different program capstone event each time.

Currently, the exhibit is using the floor plan of the Worcester Auditorium. The Worcester Auditorium, a war memorial built in the 1930's, was chosen because of the vast basement perfect for the exhibit. It is underground, has many tight twisting hallways, and the current building is unused. Worcester was also chosen because Robert Goddard, the founder of modern rocketry, lived, went to college (WPI, class of 1908) and taught as a college professor in Worcester. He would have been familiar with this place when the new field of aeronautics caught his attention and inspired him to think about a means of space travel.

In this presentation we will explain where the contest came from, especially its origins in a 2010 architectural lunar base design contest run by SHIFTboston. Cratersville was one of 102 entries, but it tied for first on technical feasibility and elegance, and was the only one that could feed itself and promised to pay for itself. The co-winning entries will be presented as the inspiration for this simulated lunar base design competition. After that it is our mission to discuss the Auditorium and the odds that the city of Worcester will take one of these visions and actually create such an exhibit. The sponsors of the contest are not committed to having the lunar base exhibit in this space, but we think it is a highly appropriate use for it. However, the greenhouse aspect of the base creates special

problems which we will discuss briefly with reference to the nearby Tower Hill Botanical Garden.

In summation, our goal is to get you ready to hear the next two papers by teams of WPI students assigned to write the technical specifications and architectural programs from which the architects in the contest (to start in January) will work. Only 22 of 102 architectural entries were technically feasible in 2010. This time they all must be. The teams assigned to make that happen are here to get feedback from technical students and educators. They also hope to encourage AE majors to team up with architecture majors entering this contest. The goal is science education and they have to get the technical details right. Further, the implications for the Aerospace workforce pipeline and funding for aerospace in the next generation could be far reaching. This is an effort to make a case for a lunar base to the next generation of voters, artists, educators and business people while fostering technological literacy about the field. If this curriculum/exhibit precedent disseminates it could be a very big deal.

Appendix B: Proposal to AIAA New England Chapter

A Proposal to have the AIAA Run another Architectural Contest with SHIFTboston

By Gregory Sharp and Joseph Cacaccio of WPI

Overview

Request AIAA Region 1 Co-sponsor of the Lunar Base Exhibit Architect Contest. In brief, co-sponsorship includes:

- Contact various AIAA student chapters (see supplementary material)
- Aid in networking and advertising needed for a successful contest
- Aid in hosting events that would benefit the contestants by providing additional information
- Host final award ceremony
- Support the final stages of the contest by planning the award ceremony
- Arrange for distinguished lecturer for final awards ceremony

The contest

Two technical groups from WPI are currently creating a program for the architectural students to base their ideas on. A program is a technical document containing the specification of the space available and the proposed exhibit design. These documents are based on the original lunar base design and headed by aerospace engineers. These programs will ensure technical feasibility from the contestants. Additionally, to ensure technical feasibility, the AIAA will have 2-3 representatives on the panel of judges. The

other judges include representatives from Worcester Public Schools, SHIFTboston, and other educators.

Co-Sponsorship

As co-sponsor, AIAA region will contact AIAA student chapters such as City college of New York, Clarkson University, MIT, Dartmouth, and RPI. AIAA will distribute provided material to the various chapters to promote the contest. SHIFTboston will be contacting the architectural programs within Region 1. The goal is to create interdisciplinary teams with aerospace engineers and architects to get the best design possible. However, it is not necessary that the architects join a team, and individual or non- interdisciplinary teams are still welcome to submit entries.

These contestants can meet and discuss with the two technical teams at an event held in February to go over the designs and ask any questions. Educators and contests will be invited to the event. This event will help the contestants better understand the designs that the WPI technical teams have drawn up. At this time, the contestants and educators can ask specific questions and concerns that have an impact of the final design. Any vague point and caveat of the program will be discussed at this time.

It is also requested that AIAA host the ending award ceremony. This event will cater to educator, architects and AIAA members who wish to hear of the contest and the conclusion. At this event, it is requested that the AIAA invest in a distinguished lecturer, to be decided at a later date.

Finally, AIAA will submit a prize a money request to Region 1 (Probably $1000) and meet their matching funds term (probably $500

<u>Corporate Outreach and Funding</u>

As stated above, we are seeking a $500 contribution from AIAA Region 1 and about $1000 from AIAA New England. However he cost of the contest will go beyond that.

Additional funds would allow more leniencies in the budget of the contest and allow for a more educational experience to be had by the contestants. It is for this reason we request aid in seeking corporate sponsors. With an endorsement from AIAA and even with some initial contacts, a connection can be made between this contest and interested corporate companies. The advertisement would benefit them and strengthen the contest beyond its current scope.

This money will not only go to prize money and the awards ceremony. It is our desire to have a web-page designed for the contest. This page will be on AIAA region 1 website, and will be designed by a professional. It is estimated that $500 for the designer to do a profession, and functional page. This will bring traffic to AIAA region 1 website from those following the link from SHIFTboston website and those looking for the contest.

As of now, we hope to have supplementary events to give the entries a better idea of the location and the program. These events will also be put on the website, but contestants close by can also attend. A portion of these funds will go into hosting such an event.

Goal

The goal of this contest is to inspire the students of today to be the engineers of tomorrow. Without engineers dedicated to a base on the moon, the parliamentary base will not be completed, which will prevent major scientific advances. This exhibit can appeal to those interested in biologists, robotics, aerospace engineering, or even chemical engineers.

Supplementary Material

Specific schools where there is an architecture and aerospace engineering major:

- Boston University?

- Brown University?
- City University of New York -> City College of New York
- Clarkson University
- Columbia University
- Cornell University
- Dartmouth College
- MIT
- NJ Institute of Technology
- NY Institute of Technology
- Princeton University
- RPI
- RIT – Master’s only
- SUNY – Buffalo
- Syracuse University
- WPI (but a very new this year Architecture major)

Appendix C: Proposal to all of AIAA Region 1 Chapter

Prize money support for the AIAA NEC Lunar Base Exhibit Architectural Contest cosponsored by SHIFTboston

Overview

The plan for a lunar base science education exhibit in the basement of the Worcester Auditorium has evolved from a vague plan for obtaining support following the development of imagery in a proposed architectural student competition to be run from Sept. to Dec. of this year into something much more specific. The catalyst for the changed plans is a NASA RFP calling for science exhibit ideas. This grant offers these ideas funding in the $100,000 to $1,000,000 range with a submission deadline of April 9, 2013. This led to a meeting in Worcester among the existing science exhibit organizations to propose a cooperative strategy of fundraising to build a new kind of interactive exhibit. The plan was to have a network of cooperating organizations each built part of the space infrastructure circa 2069 that would co-exist with a lunar base for 60 at the south pole of the moon.

While the key organizations (The Christa McAuliffe Center in Framingham Ma, the New England Ecotarium in Worcester Ma, and Tower Hill Botanical Garden in Boylston, MA) took well to the idea of sharing “visual assets” to enhance their own exhibits, they were leery of the development of a massive new lunar base exhibit. These organizations felt that the

project would be underfunded even with a million dollar grant. The counterproposal of the Ecotarium was to offer 2500 square feet of space for a scaled down version of the lunar base exhibit on their own property as a pilot study of the feasibility and draw of the proposed educational exhibit. Even that might cost more than a million dollars, but they were prepared to fundraise the additional money that they expected would be required to carry out the plan- if the funding drive was launched by a successful proposal to NASA.

The result was a phased plan in which we would try to outgrow the pilot version in 3-5 years and move to the larger site if interest in the region warranted the scaling up. Further, with coordinated projects at Tower Hill representing the 40% of the base devoted to agriculture and the McAuliffe Center playing the role of Mission Control Earth and a Space Station in Earth orbit, from which lunar mission would depart, the Ecotarium space could focus on an exhibit of the human and animal aspects of the biosphere to be created at the lunar south pole.

The Mars Foundation also sought to join the proposed collaborative, suggesting that they would seek to encourage another science exhibit in New England to seek NASA funding to put a Mars base on Phobos circa 2069 that was preliminary to building a larger colony base on the Martian surface. Should the large project go forward they proposed that the massive space in the Auditorium (38,000 square feet) be divided between a lunar base and a Mars base that would differ in some dramatic and instructive ways.

The Ecotarium would be rewarded for launching the effort by being given an exciting new exhibit in their space representing a lunar Radio-astronomy facility on the far side of the

moon. This exhibit would augment their planetarium. If another organization takes this role in the next few years, another part of the space infrastructure can be developed there, possibly a refueling depot in lunar orbit. In short, they would get a classy new exhibit suitable to their space available if the lunar base moved out on schedule. Or they get the first helium-3 mining facility near the lunar equator.

The upshot was that there was a need to continue plans to envision what the space in the Worcester Auditorium would look like mocked up as a space base, but now two contests would be needed, one for the lunar exhibit and one for the Mars exhibit with about a 50% overlap possible where the facilities would be similar. Should the city of Worcester find another use for the building in the meantime, the Ecotarium noted the undeveloped space on their grounds and suggested that at the time one might consider moving the Lunar base there was another option and they would want to move the greenhouse exhibit closer to the main facility as a joint project of the Ecotarium and Tower Hill.

The idea of moving into plants clearly appealed to them. They envisioned this as a way to illustrate an extreme version of urban gardening and agriculture for consumption rather than decoration. They also seem prepared to house the animal lab exhibit for the lunar base and to have the “teacher in space” broadcast to schools all over New England. There is a facility already built into the lower level of the Ecotarium that allows one to give and receive presentations for an audience of 200 people remotely. In short they want a lot of the lunar exhibit to stay there.

Thus, the plan is apply for the NASA grant on behalf of an Ecotarium- WPI collaborative,

encourage Tower Hill and the McAuliffe center to apply separately to equip them so as to tie into the new Ecotarium exhibit. We will also launch the architectural contest for the Auditorium largely as originally proposed except that the space offered would be 19,000 square feet. The rest being reserved for a second Mars base exhibit architectural contest to follow the first lunar base simulated science exhibit contest.

The ask to NASA for the Ecotarium would be altered just enough that an architect could be retained to work up the contest results into a coherent proposal to the City of Worcester for the auditorium site even while the public school children were gathering at the Ecotarium lunar base. It seems likely that some sort of lunar base exhibit will almost certainly be constructed if NASA provided the initial funding. There was speculation about whether NASA's Goddard Space Flight Center would be interested in adopting the proposed new facility as part of its public outreach program? The case would be strong if the first floor was an Air and Space museum featuring the kind of missions they do and a memorial to Robert Goddard.

We finally had a business plan and partner capable of carrying out the project on a reduced scale. If the AIAA and WPI teamed up to be the brain trust behind the integrated exhibits at several cooperating centers and the curriculum development teams succeed in winning over the public schools to the lunar theme, then the justification for the funding and the attendance of the students of Worcester would be a much strong bid then either working alone. Profit would come by serving educational and family audiences, teacher training workshops, and being the set for movies and possibility a TV series. Overnights by clubs and scout troops are also anticipated.

Returning to a consideration of the architectural contest that has been in planning for two years... Now that the programs are complete, one needs only to secure prize money and fund the web page development and the contest can be announced. AIAA NEC proposes that it fund the Web Page development project at a level of $500-1000 and AIAA Region 1 fund the prize money at a level of $1000-$1500. Then other sponsors can be sought to enhance the prize money pool so that more and larger awards can be given, but the event itself is definitely a go to be marketed once this detail is in place.

Assistance by AIAA Region 1 would also be sought in marketing the effort, specifically to aerospace major students in AIAA student chapters. We propose to do that by offering (at cost of travel and accommodations) six strategically located presentations by a WPI program development team at universities in AIAA Region I that have an interested AIAA Student chapter, a school of architecture, or hopefully both. Those that do not have enough interest to fund such a presentation will be offered a video recording of the presentation given at one of the universities that was interested.

It is likely that the best way to proceed is to have an AIAA chapter sponsor a talk by Wilkes on the science exhibit concept. This talk will aim at the enhancement of STEM education, getting aerospace back into the public school curriculum, and recruiting the next generation of rocket scientists. Further talks can be given at interested universities. These talks would be more in the tone of a more specific briefing on the mission and goals of the contest and how to form and appropriate team to enter. Alternatively, a local chapter can invite all the student chapters and schools of architecture in their region to attend the main

meeting and Wilkes can do the briefing part for the students just before or after the main event and direct them to the website or handouts that he distributes for further details

In summary: AIAA NEC will co-sponsor the Lunar Base Educational Exhibit Architect Contest with SHIFTboston, but do so in such a way as to exclude well drawn but not-feasible designs from being a valid entry by instituting a screening process at point of submission. An entry can be rejected on technical grounds and the architect is given a week to respond to the concerns of the technical experts if they want to resubmit. Region one is invited to directly sponsor the event or to provide resources to AIAA NEC so that it can handle an event on this scale. The key concerns are prize money, publicity and award ceremony, but in return for its support AIAA Region one will also get to designate one of the proposed 7 judges.

The panel of judges will be two AIAA NEC members, 1 AIAA region I member, 2 Boston or Worcester Architectural Society members one practicing or recently retired science teacher or district curriculum coordinator and one representative of a organization that currently runs a space oriented science exhibit.

. In brief, co-sponsorship includes:

- Provide $1000- $1500 for prize money
- Contact various AIAA student chapters (see supplementary material)
- Aid in networking and advertising needed for a successful contest

· Aid in hosting events that would benefit the contestants by providing additional information

· Support the final stages of the contest by helping plan the award ceremony (Identify suitable speakers and be sure judges are there so that their comments can be shared) as well as here from the winners on what inspired their designs.

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The contest

Two technical groups from WPI are finished creating programs for the architectural students to base their ideas on. A program is a technical document containing the specification of the space available and the proposed exhibit design. These documents are based on the technical feasibility prize winners of the 2010 lunar base design contest and both teams are headed by aerospace engineers. These programs will ensure technical feasibility from the contestants.

If a co-sponsor, AIAA NE will contact AIAA student chapters such as City college of New York, Clarkson University, MIT, Dartmouth, and RPI. AIAA will distribute provided material to the various chapters to promote the contest. SHIFTboston will be contacting the architectural programs within Region 1. The goal is to create interdisciplinary teams with aerospace engineers and architects to get the best design possible. However, it is not necessary that the architects join a team, and individual or non- interdisciplinary teams are still welcome to submit entries. If AIAA Region one is not a co-sponsor it will simply pass along the offer of AIAA NEC to provide speakers that will come to them at low cost and suggest that the students chapters be given a chance to piggyback on this opportunity.

The contest will end in December with a screening of the architectural designs for technical feasibility, followed by their being judged on the basis of aesthetics and educational merit. To ensure feasibility, the AIAA will have **3** representatives on the panel of 7 judges and the Architects will have only two. However, the educators and exhibitors will have the swing vote if they vote as a block with the architects. Since this is unlikely, we are confident that technical elegance will be as important as aesthetics in this contest. Once the winners are decided, an award ceremony will be held. AIAA NEC has already decided to use a distinguished lecturer slot for this event. It is our intention to contact Bill Nye and offer this slot.

Corporate Outreach and Funding

As stated above, we are seeking a $1500 contribution and AIAA NEC is committed essentially matching funds to the publicity and awards ceremony – which will be a public event. Before SHIFTboston is willing to announce the contest, this prize money must be ensured. Other preliminary steps to starting the contest have been undertaken.
For example, AIAA Region 1 has provided $500 so far and is expected to spend as much again on a professional web designer to help establish the contest web site. The contestants will be channeled to this site from AIAA Region 1 and SHIFTboston. From here, contestants will be able to sign up and stay informed.
However the cost of the contest will go beyond that. Additional funds would allow more leniencies in the budget of the contest and allow for a more educational experience to be had by the contestants. In short, we would like to avoid charging and entry fee and still want to enhance the pool of prize money and offer scholarships for participants to get to the awards event in Boston or Worcester.

It is for this reason we request aid in seeking corporate sponsors. With an endorsement from AIAA and even with some initial contacts, a connection can be made between this contest and interested corporate companies. The advertisement would benefit them and strengthen the contest.

As of now, we hope to have supplementary events to give the entries a better idea of the location and the program. These events will also be put on the website, but contestants close by can also attend. A portion of these funds will go into hosting such an event.

Goal

The goal of this contest is to inspire the students of today to be the visionary citizens and engineers of tomorrow. Without public will and talented engineers dedicated to creating a base on the moon, the preliminary base will not be completed by 2069, at least not by the USA. This exhibit is by its nature going to be designed to interdisciplinary appeal. It is not just rocket science and aerospace engineering, though that is critical, it will also appeal to those interested in biology, agriculture, medicine, robotics, civil engineering, and chemical engineer among other fields. Everyone seems to have a role when you are creating a biosphere in an alien environment. The AIAA will have to become more interdisciplinary if it wants to remain at the center of thinking about living and working in space during the space base era. This challenge captures the imagination and provides a lot of specific problem to solve- many of which will have spin off application on Earth after the end of the oil era.

Supplementary Material

Specific schools where there is an architecture and aerospace engineering major:

Boston University still has a minor in Aerospace and an AIAA Student chapter

Brown University no longer has an AIAA Student chapter.

- City University of New York -> City College of New York
- Clarkson University
- Columbia University
- Cornell University
- Dartmouth College
- MIT
- NJ Institute of Technology
- NY Institute of Technology
- Princeton University
- RPI
- RIT – Master's only
- SUNY – Buffalo
- Syracuse University
- WPI (but it is a very new Architecture major)

Appendix D: Letter to Massachusetts STEM teachers

Note: this letter has not been sent as part of the project. This letter can be given to MAST and they will in turn send it to teachers who are a part of MAST. It is purposely short, as time of writing this letter would only be used to gauge interest

To the members of MAST and TEAM

The American Institute of Aeronautics and Astronautics (AIAA) New England Chapter and SHIFTboston (A branch of the Boston Society of Architects) are sponsoring a contest to design a science education exhibit tentatively to be located In Worcester. While it will be designed as a review of science concepts at the 5^{th}, 6^{th}, 7^{th} and 8^{th} grade levels, it will look like the interior of a lunar base at the south pole of the moon circa 2069. This exhibit is intended to be a fully interactive experience with no equal though there is another lunar base hand on science museum project underway in Tampa Florida at present. The exhibit would be highly flexible and offer customizable class field trip experiences. The exhibit would cover Physics, Robotics, Biology, Chemistry and a variety of other science topic tied to the texts in use in Worcester and the topics mandated by the state curriculum frameworks. . Furthermore, each topic has a lunar theme that applies the concepts in a new and exciting way. The lunar theme has been tested a curriculum development project and has proven very effective in engaging the students and getting them to think “out of the box” in solving design problems. It seems that you learn more about how things work on Earth when you are trying to create functionally equivalent system in an alien environment.

The exhibit has the potential engage students interested in many fields of science and to spark more student creativity than any other exhibit thematic of which we are aware. .

However, this project is still in its infancy. Currently we are at the point of holding tan architectural concept contest for college students to generate a range of approaches. Then a serious architectural team will take the best ideas and other input to design the actual exhibit. The design contest will be based on the floor plan of the 37,000 square ft basement of the Worcester Auditorium. Above all, each exhibit design must be technically feasibility and must adhere to strict guidelines reflecting the hostile lunar environment as well as accurately conveying scientific principles. On the other hand, the winner of the contest should be the design with the most potential for teaching the students.

Therefore, it is requested that there is a judge to represent the educators who will use the exhibit. The Science Educator judge would sit alongside representatives from SHIFTboston, AIAA, and Tower Hill Botanical Gardens. The panel of judges will determine the winners of the architectural contest.

If the concept of this exhibit interests you enough to consider serving as a judge or helping plan the awards ceremony, please contact a member of the WPI based student team helping Professor John Wilkes plan the event. Help is needed refining the life science focus of the exhibit and to ensure educational usefulness as well as managing the contest. The person to contact for refinement of the educational portion of the exhibit is **contact info here**. If you would like to learn more about the exhibit in general please contact **contact info here**. If you are willing to help out as a judge please contact **contact info here**.