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Planning a Lunar Base Exhibit Design Contest

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Abstract

The goal of this project was to design and run an architectural contest for students that would produce visuals for a lunar base exhibit to promote building the real thing. This imagery would help the AIAA and science educators in the public schools to envision and appreciate the science education potential in an interactive lunar base themed exhibit, inspired by the idea of a hands-on children's museum. We have started to promote to the city of Worcester the concept of an air museum and a futuristic space exhibit in an unused public building, probably the Worcester auditorium. This project has the potential to catalyze science education in the city of Worcester, by making field trips a routine part of the grade 5-10 science curriculum.

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Introduction

In the summer of 2010, SHIFTboston hosted an architectural contest to design a lunar base. This contest had two categories, “Let’s get serious” and “Let’s have fun”. Many of the 102 entries showed artistic creativity, however not many conveyed a good understanding of the technical requirements of actually having a workable base on the moon. Out of about 100 entries, only 20 could be considered at all close the mark and technically feasible enough to be considered for feasibility prize judging. There were twelve designs that were advanced to the final round of judging by a team of three WPI students, as well as being co-judged by an independent study student and three outside experts.

There were two standout designs among these twelve “finalists” One was by Tom Schmitt, an architect from Hong Kong, and the second was Team Goddard from Worcester, MA, which included WPI students, alumni, and faculty, architect Dan Benoit, an interior designer (Prof Kimball of Becker College) and a member of the Mars Foundation (Bruce Mackenzie). Both groups won a shared first place award for technical feasibility based on both qualitative and quantitative analysis from two 4 WPI student and 3 outside expert reviewers recruited by SHIFTboston. The winners’ visuals are the visuals that our team has been using as publicity for our events and programs.

The original goal of our project was to run a contest in which teams of contestants designed an educational, lunar base themed, science exhibit that would be specifically built for the Worcester Auditorium. However, after a few rounds of discussion with Kim Poliquin of

SHIFTboston, we learned that SHIFTboston would not sponsor a contest where architects would create building specific drawings and not be guaranteed to get a contract and be paid for them if they won. Worcester was not committed enough in their eyes. Ms. Poliquin instead suggested a mobile unit where a more modest exhibit could be taken on tour around the eastern United States and be set up either in an extra space at a school or has its own container in which students would go inside and experience the exhibit. We did not like this idea. It did not seem possible to get the scale and impact of a full sized exhibit, because of the constraints of having a mobile exhibit. Instead, we thought a contest for architectural students would be a good way to produce the imagery that we wanted, without having actual architects make plans for an already existing building before the City was committed enough to offer a commission. Students want resume items and are not as worried about getting paid for their work if they can get professional recognition. Ms. Poliquin agreed, though she noted the SHIFTboston had never run a student contest before and she wanted to start small- with the 20 or so architectural schools in the Northeast US.

In this contest, we envision that architectural students could work together with technical, educational, or artistic students as an interdisciplinary team to create imagery and text that describes an educational and futuristic lunar base exhibit. This contest is meant to create the beginning of a movement that would change the way that students are taught math and science, particularly in the Northeastern United States. Students are not being inspired to pursue a career in STEM because the average public school science class is too textbook bound. Interest in engineering generally and aerospace fields in particular is limited and replacing the 25% of the field of aerospace that is close to retirement may not be possible without recruiting foreign experts. We believe that an interactive and fun exhibit with a space theme but truly interdisciplinary in character would change the game and create widespread fascination and interest in science and technology more generally and aerospace in particular. At present space has little visibility in the public school science curriculum as presented in texts.

SHIFTboston Previous Contest

In the 2010 contest sponsored by SHIFTboston, the "Let's get serious" portion of the contest produced two winning designs. Each of these designs showed an in-depth understanding of the technical requirements of living and working on the moon; however they had a few key differences that distinguished them. The Team Goddard lunar base exemplified what an advanced, futuristic base would do to support itself economically, and how it would function to be sustainable, while Tom Schmitt's design took the set of guidelines produced by the author

(Mark Cohen, an AIAA Space Architect) of the program and applied them to a tee, from square footage requirements to the number of bathrooms. Tom's vision for the lunar future was a reflection of Mark's, a scientific research facility and relay station that would work on the moon but was more generic and might makes sense elsewhere as well.

By contrast, Team Goddard's base had an economic, as well as scientific, case for the existence of the base but its design was specific to the South or North Pole of the moon and would make no sense anywhere else. Another difference between these two bases is the fact that Team Goddard's base was designed by many technological and artistic experts, from architecture to interior design, while Tom Schmitt worked as an independent professional, taking on the challenge of the whole design himself.

From these two designs, we were able to draw an idea of what a futuristic lunar base would look like, and of what it would actually do. Tom had the fully developed human habitat and laboratories while Team Goddard had the rest of the Earth, space based and lunar infrastructure for a successful heavily robotic gas and metals mining camp in place,

Events

As a way of getting Tom Schmidt to New England to get his award in Boston, The AIAA New England chapter arranged to have him designated a "distinguished lecturer" of the AIAA. We were asked to organize his New England tour and awards ceremony in return for getting privileged access to him to study his path to success, by interviewing him. About a month before Tom Schmidt arrived in Worcester, we were trying to think of the best ways we could not only give Tom's project publicity, but also how we could use the attraction of an actual design floor by floor like Tom's design. Knowing that we had about a week with Tom, we reached out to student groups (Student Pug wash and the WPI chapter of AIAA), as well as the New England Chapter of the AIAA.

We settled on three events where Tom would be present, actively presenting and discussing his design. We determined that Tom should receive his award as well as present his design to colleagues at least one event. Ultimately we decided to have Tom give his presentation back to back with one by a few members of Team Goddard, who would give similar presentations of the parts of their base that they were responsible for, as well as receive their awards. We also wanted to show students at WPI the results of the hard work put in by the architects, we arranged another event, at WPI, where again the designs would be presented, and questions would be taken.

Boston Awards Event, Boston Society of Architects

After talking to Kim Poliquin from SHIFTboston, we arranged a time and date at the Boston Society of Architects where Team Goddard and Tom Schmitt would receive their awards. Anthony Linn, the Chairman of the New England chapter of the AIAA, agreed to be there to present these awards. We wrote a summary of the contest and of the two winning designs for Mr. Linn. Tom Schmitt and Team Goddard would present their respective designs, with the present members of Team Goddard answering questions about their specific role. Any team member present would receive their award certificate. Others could be recognized at the next event back in Worcester. The actual event went quite well, with entertaining discussion and ideas being thrown around the room, although the turnout was pretty slim. About half of the members of Team Goddard were present to get their recognition along with Tom Schmidt.

The AIAA provided funding for Tom's award as well as travel and food for the event, while SHIFTboston and our team acquired drinks and reserved actual room the event was held in. A few members of the Boston Society of Architects made the presentations, and seemed to enjoy hosting this type of technologically advanced and forward looking discussion. Despite the modest turnout, we thought that the event was a success, allowing us to get the ideas that we wanted to get out to the right people. It also allowed us to get perspective on what they thought about our concept as well.

WPI Lunar Base Event

One of the most important things we wanted to do was to spread the idea of a feasible and self supporting lunar base, and the educational value that is involved with that kind of thinking. So immediately we reached out to WPI's student AIAA chapter, and set up a presentation in which Tom and a few members of Team Goddard could talk about their ideas to WPI students and faculty. Also, the members of Team Goddard that were unable to get their awards in Boston would receive them at this event.

The AIAA student chapter had said they would be co-sponsoring the event; however they provided little help in the publicity and set up process. Also, few of the members of the AIAA chapter were actually able to attend. However, overall student and faculty turnout was excellent, with all the seats in a fairly large classroom full of interested minds, sparking a great discussion about both the designs and the possibilities of what comes next. The night's presentation went without a hitch, and was a very large success, as we got the word out to many thinkers on campus that something like a lunar base exhibit would be a very powerful educational tool.

Concord Observe the Moon Night

We were invited by the McAuliffe-Shepard Discovery Center to present in Concord as a part of their International Observe the Moon Night. Tom Schmidt would be back in Hong Kong by then, so they arranged to have him piggy back his talk onto a presentation about galaxies in the planetarium. They held Team Goddard for the "right" night to be featured. We thought this would be a great opportunity to show Team Goddard's lunar base ideas to a new audience as well as talk about our ideas for a lunar base exhibit.

Professor Wilkes, of Team Goddard, opened the event with a generalization of what we had done so far, and basically outlined what our reasoning was. Then we each talked about a part of our project so far, from the overall concept of our project to what we would like to see done at the Worcester Auditorium, or as we were careful to mention, somewhere else like the McAuliffe-Shepard Discovery Center. Though there weren't as many people at this event as we'd hoped, the audience of 15-20 people seemed very interested in the lunar base concept, and all seemed to agree that an interactive lunar base exhibit would be an excellent educational experience.

This field trip also gave us the opportunity to explore the McAuliffe-Shepard Discovery Center, which, with its interactive displays and futuristic design, gave us a very good idea of what our exhibit might look like. The outreach trip to the McAuliffe-Shepard Discovery Center may have been fortuitous since it gave us an idea about how sites all over New England could cooperate in this venture. Clearly there will not be just one site on the moon developed so how can one mimic communications with other bases on the lunar surface, in space or back on Earth? In effect any museum with space for at least one room to be a control room (or mission control) can take part and be an integral part of the lunar base association that we envision to mimic operation over a substantial expanse of the moon as part of our mission.

Although the museum exhibit that we currently have planned for Worcester will be the center of attention and communications hub because of its highly developed educational goals, other locations will hopefully be involved. They would bring a much wider array features that would be part of a true lunar base complex than it is possible to convey in just one building. We hope that in the future the McAuliffe Center could partner with the larger exhibit and bring another piece of the lunar base such as an outpost on the side of the moon opposite Earth, or an emergency life support base. Similar locations we also wish to include in the exhibit would be the Tower Hill botanical garden (as the major lunar greenhouse) and the Ecotarium (as an astronomy and astrology center focusing on the moon). Perhaps the Boston Science museum could be Mission Control on Earth. By adding more than one location and type of exhibit, the educational vision can be expanded and varied depending on the needs and course studies of the students.

Study of Winners

In the SHIFTboston contest, there were over 100 entries in the architectural contest. The first round of judging was based mostly on a creative design and the "just for fun" portion of the entries to the contest were not excluded. This judging was done mostly by a panel of experts recruited from Harvard and MIT by SHIFTboston combined with a few well known architects.

Their instructions were not to rule out a design that was not feasible, but to recognize and reward the use of any reputable scientific ideas or sources. They were not to exclude the just for fun category or rule out the bulk of the entries.

However, the AIAA (American Institute of Aerospace and Astronautics) wanted to judge the entries based upon the technical feasibility of the base. With this need, the AIAA sponsored a second group of judges that were engineering students, rather than architects. A group at WPI took on the task of creating a way to determine the probability that the designs would be able to exist on the moon. They concluded that there were only about 15 entries that qualified as technically feasible, (and about 5-6 more they could "fix" with modest changes to increase radiation shielding). However, they rapidly found that their point system kept pointing to two entries that were head and shoulders above the rest in terms of technical feasibility. In the end multiple efforts to rank order the top 5 kept shifting with of these two was first or second. Finally they decided on awarding co-winners by calling it a tie for first place (between Team Goddard and Tom Schmidt). Both of the winners however used completely different techniques in order to come up with their base concepts. In this section, we will discuss our findings in how the winners created winning designs and why we believe that teams are the best way to increase the odds of creating a high proportion of space feasible architectural designs in the next round of the contest.

The first winner was Team Goddard from WPI. This team consisted of Dan Benoit (the architect), a biologist, an interior designer, a group of 3 WPI students (ME, Biomed and Robotics), as well as sociologist John Wilkes (as a team manager) and Bruce Mackenzie a technical expert with general credentials from the Mars Foundation. This team was very diverse and dynamic with a large group of interests and expertise however with this diverse team there was a different set of issues. We created a short compilation of the interviews with the team as they talked about the issues involved in creating of their base. One interesting point that was brought up with Dan Benoit was the conflicts between him and the technical experts; especially Bruce and the WPI students. The engineers wanted to make sure everything that Dan incorporated in his design was technically feasible and radiation tight while Dan wanted to make decisions based more on architectural beauty and aesthetics taking advantage of the view and some practical shortcuts. This complicated the relationships between the architect and his team however it ended up creating a base that was technically feasible and expanded the role of the interior decorator who was called up to do with illusions what Dan could not safely due by reducing radiation shielding.

The other winner, Tom Schmidt, had an entirely different approach. He worked alone and was also far from the contest sponsor because he works and lives in Hong Kong. This caused a different type of complication because he was not a technical expert and did not have the experience with aerospace and the science and engineering that goes along with it. His solution to this problem was to follow the specifications in the program exactly and lean on Mark Cohen, who luckily knew what he was doing most of the time. Team Goddard argued with the program, but Schmidt followed it and it only led him seriously astray into unnecessary features once. Everything from the exact space specifications and radiation shielding was accounted for per the program which gave him the ability to create a technically feasible base as well as making it a professional looking architectural drawing.

Taking into account all of the presentations and accounts of the design process from the different members of Team Goddard helped us to realize that an interdisciplinary team had the best chance of producing an original and dynamic as well as technological sound design. Since it would be our job to write the program we did not want anyone trying to copy it slavishly without understanding the larger logic of the two base designs that inspired us. Tom was unusually knowledgeable and "got it" why Cohen's spec were there. Even so he did not have the confidence to depart substantially from the rules and innovate very often.

For our contest, we want to see a higher percentage of technologically feasible ideas, and some radical and original thinking, so we decided that we would recommend that teams be composed of an architectural student or two, one or two technical students, and possibly educational or artistic students. We feel that the multi-faceted team that was Team Goddard really put together a complete design, from the development of the glass and water shields that stopped radiation but allowed actual light into the base, to having screens in the public areas making it appear as if there was a scene outside other than the lunar surface. We would like to see similar results for the designs in the future contest, as it is this kind of team work that produced such great imagery and conceptual advances for Team Goddard.

Both of the winners had a different approach to creating something that would actually work. One entry used a group and variety of experts and the other followed all of the rules of the contest and was a balanced and beautifully rendered professional architectural element of a base. In trying to do so much the Team Goddard artwork was fragmented, and a later group of WPI student pulled together a fine angle perspective picture of its core elements that started to rival the artwork of Schmidt. The designers were very different in the makeup of their teams. There were different characteristics that were drawn from the different designs that could be incorporated into an actual lunar base. Because of the differences in how they actually made their designs, the final specifications were very different. This was actually very good for the overall purpose of the contest because it helps to get multiple views on what a feasible lunar base could look like.

In our review there was a focus on a second round of feasibility judging by the AIAA because of the ludicrous entries that were submitted and considered by the first round or architectural judging. Though those entries might be fine for an architectural design contest, they had no place in a contest to design an exhibit that can support science education and convey what the lunar environment is like. When one has to get the science right, there is no place for the designs that ranged from a roving lunar base to bouncing bubbles on the moon which in no way would be able to work (especially against radiation). The rules had specified a base for 60 and some could accommodate about 6.

One could tolerate some creative leaps because the base represented something that could be invented in the near future, i.e. before 2069. Hence, some mentioned fusion reactors and other radiation force fields, and got away with it, but windmills and oil derricks were beyond the pale. That kind of thing would confuse the children. The "serious" designs should incorporate materials and technology that is either current, cutting edge, or something that could easily exist in the next half a century. When designs got "silly" or did not use this designs or materials, they are not very useful in displaying the reality of a lunar base and would not convince people to support the idea that one could actually exist. The educational value in the winning and honorable mention designs is great enough that the previous team working on this issue presented them to 5th grade students (10 years old) who were very excited at the idea that one of these could be built in their lifetimes, even up to the point of asking "when will this be on the moon?".

The last objective we had by looking at the winners of the last contest was pursued by asking the question "how could we make our contest better?" By looking at the results of the last competition, we found out what makes a great contest. We also were able to get an interview with Tom Schmidt when he came to the United States to accept his award and to talk in California about the contest. He said that he was successful because he took the rules and followed them exactly. In his words he put on different "hats" in order to see a problem in different ways. First he will put on the hat of a maintenance worker at the base to design in a way that will work well for him. Then he will look at the design from an architectural standpoint, and then a scientist, and then as someone who lives there. This allowed a well rounded design that would be successful for all people involved. Because the program had exact specifications, his drawing could be very accurate. However he said that working alone has its drawbacks. Without technical support Tom found the program had to be very exact and detailed in order for him to be able to produce technically accurate material. He also only had his interest in space and science to fuel his research to find out what is technically accurate, rather than someone who has studied the subject intimately to confer with.

For that reason, we will be mandating, facilitating and encouraging (but not requiring) entrants to be in a team with at least one architect and a technical expert (science or engineering) in order to have the best odds that a team will provide both technically accurate result as well as a architecturally pleasing and sound design. Tom Schmidt's entry was an exception to our idea that interdisciplinary teams create the best product for two reasons. One was because he was a seasoned professional who designs self-contained resort hotels on islands for a living and knew exactly how to create a professional and correct standalone design. The other reason was because he followed the high detailed and specific program without creating many technical flaws that would impact the reality of the design.

In our new contest we will be working with students who do not have the depth or relevant experience that Tom had. This is a major difference since we need to create professional artwork. By incorporating teams of different specialization, we will balance the technical portions with the artistic and architectural portions by discouraging having just one person try to do it all. This also lets us be less scientifically specific in the program, while allowing for greater artistic freedom than Cohen allowed to those who took the rules seriously.

Planning an Exhibit Contest

After we met the winners of SHIFTboston's Moon Capital contest, we had to decide the best way to create the visuals needed to bring our idea of a lunar base exhibit to a reality. We faced two main options: recruit the previous winners or run another contest.

The first option was to recruit the winning architects from the previous contest, Dan Benoit and Tom Schmidt, to work together to design an exhibit based on their base designs. The first problem with this idea is that Tom Schmidt lives and works in Hong Kong, which would make meeting with him again almost impossible. This would make it very difficult for Dan and Tom to collaborate and combine their ideas. There would also be the issue of payment. In order to ask either of these architects to design a lunar base exhibit, we would have to raise enough money to properly compensate them for their time.

The second option was to design and run a new architectural contest. This time the task would be to design an exhibit as opposed to an actual lunar base. With a contest you can get a wider range of ideas than by choosing a single architect or group to design the exhibit. We would be faced with the task of writing the contest's program, which would have to be specific enough to avoid the problem we saw in the Moon Capital contest where only about 15% of the entries were technically feasible. In addition, we would need to find someone to run the contest and would have to raise sufficient prize money for the winners.

We decided that a contest would be the more effective method for creating visuals for the exhibit. However, Kim Poliquin, director of SHIFTboston, did not want to sponsor the contest we originally envisioned. She thought that professional architects would not be willing to participate in a contest to design plans for a building unless they were guaranteed to get the contract if they won the contest. Since we had neither the full support from the city to build an exhibit in the auditorium nor the funding to build the exhibit once designed, we could not guarantee that the winning exhibit would actually be built. We realized that Kim's concerns were legitimate and we had to reconsider our idea for a contest.

One possible solution to this problem was to make the proposed exhibit mobile. Because it would not be tied to a specific building, architects would be more willing to enter a contest to design a mobile exhibit. A mobile exhibit has the advantage of being able to travel throughout the region to different school systems, extending its audience to schools that would be too far away from a fixed exhibit to send its students for a field trip. If the mobile exhibit was successful, it would also be easy to create more using the same plans to cover other regions. The plans for a fixed exhibit would depend too much on the specific building to be used to create a second exhibit. The main problem with a mobile exhibit is the limit in complexity you can achieve while still making the exhibit mobile. You could design an exhibit that would fit in a trailer that would require very little on-site setup, but it would be very difficult to portray all the key sections of a lunar base in such a small area. On the other extreme, you could design an exhibit that would take a day to set up at a school in a gym or several classrooms that could stay in one location for a few days to a week at a time. This would allow you to design a larger, more complex exhibit that could be visited by all schools in the surrounding area before moving to the next location. The problem is that most schools do not have an area that could be dedicated to an exhibit for up to a week. We decided that our vision of an educational lunar base exhibit would not be able to be compressed enough to become mobile and still have the same educational value for the students that would visit it.

The problem is professional architects in the current economy are looking for solid contracts, not the modest prize money and personal recognition one can from a general vision kind of architectural contest. This led us to look toward a different audience: architecture students. Student architects are more likely to enter a contest that will make a good addition to their resume. Some colleges might even offer course credit for students that enter the contest, either as in independent study project or as part of a class. Prize money of $1000-5000 for the winners would also be an incentive for students but not professionals to participate. In order to target the contest at students, we needed to simplify it somewhat. We cannot expect students to produce architectural drawings in enough detail to actually construct an exhibit from. Instead, we decided to ask only for concept drawings of their vision of a lunar base exhibit. These basic drawings should be enough to use to get the support needed to actually build the exhibit. After enough support is won, a professional architect would still be contracted to create the final drawings for the construction of the exhibit, based on the concepts derived from the winners of the student contest. The students get cited, and that will advance their careers and they can show what their work inspired.

Kim Poliquin agreed to run our new idea of a student contest. Though SHIFTboston had never run a student contest before, they felt like they were in a good position to recruit architecture students to participate. Because of their support of the technical feasibility category of the previous contest, we also wanted the AIAA to co-sponsor the contest. The AIAA would be able to promote the contest among technical students, and we need both architecture students and technical students to create the interdisciplinary teams we envision.

The Next Step

The last part of this project was to design a contest program for architectural students (as outlined in the previous section). We did not want to do this on our own, so with Dan as a consultant and reviewer we have drafted a first approximation of a contest program and outline for this contest. Dan's reaction has encouraged us that it will fulfill the basic requirements to give architects the information needed to design a realistic exhibit. However, it will need some tweaking by the SHIFTboston staff. As noted, we have consulted Dan Benoit as a resource for this part of the project and he has helped us immensely to create a usable program by pushing us for specifics. The major issue that we had trouble with was keeping the program simple and also giving enough background so that the participants know what is important in the judging and where they have latitude. We also want a realistic scenario and to convey why this contest is important in political, economic and educational terms for the host city.

The contest itself will need a large amount of support to actually happen. To make a lunar base exhibit a reality will need a substantial amount of money and support beyond the resources we have at hand. Raising that kind of money will require a local consensus and national support from a variety of supporters. One resource we have done some research on that could be a very valuable fund rising resource is the Planetary Society. The most interesting this about this sponsor would be that the head of the organization is currently Bill Nye, commonly known as the 'Science Guy' to those who watched his educational show growing up. Bill Nye is very passionate not only about space but also about education, especially with interaction and student involvement in hand on learning. This makes him a perfect candidate for the support of this project, way further than just the contest. Recruiting him to come to Worcester and endorse the concept is something that the IQP group that is taking up where we left off should look into.

As for the funding for the contest, we hope that the AIAA will foot part of the prize money for the contestants– at it did for the first SHIFTboston lunar base contest. AIAA Region one provided $1500.00 and SHIFTboston got others to support its Moonball prize awards event. Though we have made no further plans on how that prize money will be raised and awarded, we do want there to be a presentation of the designs in a formal fashion, either being all the contestants or if there are too many, the top entries.

The tentative plan is to present at the Young Professional, Student, and Educator (YPSE) conference held yearly in the AIAA Region 1 (the Northeast) which is also run and sponsored by the AIAA national office, normally at the John's Hopkins Applied Physics Lab in Laurel, Maryland. . This would be a perfect fit to the contest as it has to do with education, students, and of course aerospace. Ideally, if the City of Worcester is actively involved and excited in having the museum in its own city, they would attempt to host this event. This would bring a dozens of aerospace students and teachers into the city and be a great way to show that Worcester is excited about this kind of science education and it would enhance the overall support that the museum concept has in the city if it was clear that it would attract conferences to the city.

Another important aspect that this contest will need to succeed will be publicity to the contestants, possible sponsors, and the public. Currently, we have the support of the AIAA NE Chapter and the group SHIFTboston. The next group will have to approach AIAA Region 1 and national about both prize money and a distinguished lectureship for Bill Nye. They would also approach local companies like the Dave Clark company (they make space suits) for contest support to enhance the prizes and cover operating costs. While right now, SHIFTboston will be working with the next team to contact architectural schools to try to find students and teachers that would like to get involved with the project, there will need to be much more outreach to give this contest the momentum to take it all the way to a real exhibit.

Another organization that we would like to get involved is the International Space University .If ISU came to Worcester that would help make Worcester more than just a city where Goddard came from 100 years ago or that a children's educational exhibit is, it would turn Worcester into "space central'. The International Space University (ISU) is an organization that trains the managerial and technical supervisors that want to run space agencies. Hence, it teaches space sciences, management, law, policy and other classes about anything that would be related to space. They are currently located in Strasbourg, Alsace, in Northeast France however they have a North American office primarily used for recruitment. The ISU currently does not have an educational facility in the United States; however, they want to open one. A prime location next to the Worcester Memorial Auditorium exists right across the road. Another unused public building, the state owned (city's old) courthouse, would make a perfect location for the addition of a space university. It would unite not only the colleges of Worcester and city in developing an interest in space as a field of study, but also become a center of excellence for the entire country.

Students from around the country (and world) would come to study here and could count this as their 'studying abroad' where they could come to Worcester for a semester or a year and get a minor in space studies. Though we could not add this idea or dimension to the overall goal in the design contest because of the complexities that would exist, this idea would play a major role in the overall development of the plan for Worcester to be the central player of space education for the country as a whole. The educational exhibit would thus be cared for and developed by the perfect set of students in the relevant fields.

A follow up group is necessary for the future success of our project. The next group, beginning with an independent study in the D term of 2012, will need to continue to build momentum for the contest, work with sponsors, recruit participants, and if finances permit, run the contest in a basic sense. The next IQP group would actually run the contest and act as the support group, answering questions and creating communication between architects and the teams.

Conclusion

There is a need to change the science and technology education system for younger students for many different reasons, the biggest one being the relatively modest levels of interest in science evident among American coming out of the public schools. Something is turning them off to field that are important to the national economy and where there are relatively good job prospects, Currently, the United States does not have a very large proportion of people coming out of high school interested in pursuing engineering and coming out of college looking for careers in science, aerospace and related engineering , Only 2% of all the jobs in the country (Bureau of Labor Statistics)are in this field and even those we have now will be hard to replace as they retire if one is limited to native born talent. It puts a damper on the advancement of technology and space travel and stifles the growth of science when the talent pool is so limited. The overall goal of this project is to stimulate the interest of students to increase the amount of people going into engineering and aerospace by giving them an unforgettable and highly stimulating educational experience in science class with a clear emphasis on applying that knowledge to solve challenging problems. Living and Working in space is just an illustration- but an exciting one.

This contest provides a way that one can start creating a different educational experience more engaging than just a museum field trip, a movie, or reading in a book. We want to create an environment where students get exposed to a spectacular subject which is the dream of many young kids; to be an astronaut and be explorers in space. But this is more than just a fantastical vision for kids to dream about, this will also teach the students legitimate educational topics that will fuse with their classroom instruction and create an environment of solid science education that can make some of those dreams come true.

We believe that an exhibit, inspired by the Shift Boston winning designs but designed from the imagery created by architectural students, could get the city moving toward funding something really special that gives the young children that truly awesome and breathtaking field trip. Taking the winning designs from the SHIFTboston contest, one can draw an idea in their own mind of what a future base could look like, and we think that the imagery could also inspire college student team including architects to create some really great ideas that would shape our futuristic lunar base exhibit. We also believe that this work could be taken as course credit, given approval from faculty at each school, where the teams of students could be advised while producing their designs.

This is more than just a fantastical vision for kids to dream about, this will also teach students legitimate educational topics that will fuse with their classroom instruction and create an environment of education. This capstone experience would strengthen the space based science curriculum initiative already under development in the Worcester Public Schools.

The overall future that we see is an interactive, multi-faceted, educational, lunar base themed exhibit geared towards stimulating our nation's youth to get serious about their technical studies. We envision many different organizations participating to really increase the interest that our young school children have for the science and technology industry, especially in the aerospace field.

Our program does not require that an entry use our example building, the Worcester Auditorium, as the basis for their design. They can get a local building approved. However, we intend to make it so easy to use the specifications of this building in Worcester that most entrants will not bother to scope out an alternative venue. We do want Worcester to be the site of the central mission control station but it should be supported by a web of other groups and organizations. The 'biosphere' could be located at the Tower Hill Botanical Garden, while an outpost building could be exemplified at the McAuliffe-Shepard Discover Center in New Hampshire, or at the Ecotarium, in Boylston Massachusetts. All of these locations would provide excellent educational experiences, and could really show the youth in regional schools how this network of systems really could exist on the moon, inspiring them to pursue education in the science and technology field to realize this vision or dream.

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Appendix A:
Lunar Base Exhibit Contest Overview

A Base on the Moon

A link for the description from Team Goddard (one of the winners from last year's contest) will be on the contests website page. The case for a base on the moon has been going on for years and will continue until we finally succeed in creating a colony there. Though in the past few decades, the support for a lunar base has shrunk because of money and a reason why we should go there, the educational value is still a very important cause. A base on the moon would be a stepping stone to far greater and other-worldly aspirations that humankind has yet to experience but yet still something that everyone here on Earth could continue to reap its benefits.

Goal of the Contest

The debate about how to carry out space-enriched science education on a city or regional level has reached an interesting point. People are asking what kind of exhibit is needed to go with the 5th to 10th grade spiral curriculum that is being piloted in Worcester, MA under the sponsorship of the AIAA New England, and they want images. An architectural contest for students is being planned for the fall semester of the next academic year to produce compelling images that explore the possibilities.

The mission of this contest is to produce the kind of imagery needed for the AIAA experts the politicians and science educators in the public schools all to envision and appreciate the science education potential in an interactive lunar base themed exhibit which is inspired by the idea of a hands-on children's museum. The facility we envision would fill at least one floor of a building. It should be able to provide a capstone experience for classes of students wrapping up a month-long space enriched unit which effectively reviews key concepts they learned in a semester's worth of science classes. From a teacher's perspective it could be considered a review for the state achievement science test at that grade level. From a space enthusiast's perspective, every year's field trip should be different so that over six years students get a substantial orientation to the science relevant to living and working in space, particularly on the moon. The emphasis would shift from geology to biology, chemistry, robotics, physics and finally overall system integration in the different years of the program, so the base exhibit has to support them all well.

Sponsors, SHIFTboston and AIAA New England, see this contest as a spin-off of a prior lunar base architectural contest held May- Sept. in 2010. This contest produced two exceptional designs for a circa 2069 lunar base (out of over 100 entries) that were also judged to be technically feasible. We are looking for teams of architectural, engineering, and education students that would try to evoke the essentials of these winning designs in an exhibit that would be able to fit in an underutilized urban public building in the Northeast United States.

Who Would Build This?

In this scenario, we are assuming a full financial funding for the building of this museum. Specifically, the longstanding political tension between the colleges and universities in a city (about 10 colleges in and around Worcester, MA. including 30,000 students in all) is resolved as follows. This city wanted $100/ student per year as PILOT (Payment in Lieu of Taxes) from these tax exempt institutions. They refused on the grounds that they already contributed a great deal to the economy and that would raise tuition vis-à-vis competing colleges. Then they reconsidered on the grounds that if they knew the money was being used in such a way that it would make Worcester a better place to go to college, it could be a win-win. Hence, they agreed on the condition that they could decide on what major public project to jointly support in the "Gateway" of the city where students and their parents get a first impression of Worcester and several major buildings were vacant and deteriorating.

The decision was made to partner with the public schools and focus on improving science education and also try to create a destination that would bring visitors to the city. Hence the City gives the colleges 50% ownership in an Auditorium building built in the 1930's and large enough to gather 9000 people for an event. It was considered worth $200 million but it needed $50 million in renovations. Hence, it would require about 16 years of PILOT to restore the building completely but only about 4 years to get it to the point of opening the doors and starting to have a revenue stream again. The city was already putting $100,000 into maintenance of the roof each year with no return, so it committed to continue doing this for 10 years.

Given an assured PILOT revenue stream the City could borrow the money needed to fast track the project and get the building restored in 5 years. Now the question was what to do with the building, especially the basement area considered most suitable for a lunar base exhibit of a semi-permanent nature? Only 10% of the money would be needed to restore that level. The main work in restoration would be on the ornate main floor with one of the 3 largest stages in New England and a World War One era aircraft carrier elevator installed in it to lift things up to the stage- sometimes a whole orchestra. There are massive balconies as well so 90% of the time and money would be spent on the cavernous first or main floor.

The challenge on the first floor is to leave it flexible so that a moveable exhibit that complements the Lunar base can be there much of the time, but it can all be cleared away to have another event at which Students from all the colleges, or the 5 high schools in Worcester can gather. It should also be a venue one can rent. The most interesting proposal for the complementary exhibit so far is a memorial to local hero Robert Goddard, Father of Modern rocketry. He graduated from nearby WPI in 1908 and went to graduate school and taught at nearby Clark University. He worked on bazookas for the US Army just before World War II in a building on the WPI campus a few blocks away that is still there.

The proposal is to have an air and space museum tied to the era in which Goddard was active in the city and the building itself was built. Hence, on this floor one would get to see that state of aeronautics that Goddard saw and drew inspiration from to leap beyond the atmosphere that supported airplanes and build the tools that would allow a space age to emerge. He enabled a moon landing which occurred in 1969 based on WW II technological breakthroughs. So, one gets to look at the first half of the aerospace push that led to the moon in about 60 years. Then one goes down a level into the future about 60 years to a circa 2069 Lunar base built 100 years after the first lunar landing of the Apollo program out of primarily local lunar raw materials and designed for 60 people but expandable to 6000 over the next 60 years.

Note that a 5th grader age 10 seeing this exhibit will be astronaut age (about 40) in 30 years or about the year 2045. That is when the first generation lunar base that prepares the way for this second generation lunar base would be under construction. At their age 65, end of career, it will be 2070, and it will be completed in time for them to visit it in retirement. Their children will run it.

Background

In 2010, SHIFTboston sponsored their Moon Capital lunar base design competition. This contest actually had two categories, “Let’s Get Serious” and “Let’s Have Fun,” giving architects the option to design a unique and visually pleasing lunar base without regard to technical feasibility. Out of the 102 entries to this contest, only 15-20 were considered to be technically feasible depending on how strictly one defined this term. . Of these, there were two standout co-winners for technical feasibility, Team Goddard (led by Dan Benoit and John Wilkes) and Tom Schmidt. While Tom Schmidt created a very practical design by following the program closely, Team Goddard did extensive research on how to make their base self-sufficient in terms of food and then went on to design an economically self-supporting heavily robotic mining facility on the Moon. The submissions by both these teams, as well as several of the honorable mentions, are available to the contestants in this follow-up contest.

For more information about this previous contest, see:

http://www.shiftboston.org/competitions/2010moon.php

Team Goddard's submission: http://users.wpi.edu/~timj91/iqp/goddard.png

Tom Schmidt's submission: http://users.wpi.edu/~timj91/iqp/tschmidt.png

This contest will differ in several ways. First it is a student competition with undergraduate and graduate student divisions. Second, technical feasibility was a separate category of judging from aesthetics in the first contest. This time passing a feasibility review is required for an entry to be considered on aesthetic grounds.

This is a science education exhibit and the entry has to get the science right, and thus produce something that would work in the lunar environment. One of the winners last time

(Schmidt) had exceptional science background. The other architect (Benoit) had a diverse technical team to help-and frustrate-him. In the end only 17 out of 102 entries passed muster as close enough to technical feasibility to bother judging. This time we want that number to be 80% or more and are encouraging team entries in which an architect is working with at least a science or technology major and preferably more than one techie and an education major. If an architect is working alone without a science and technology partner he or she will be supported by a team of consulting students at WPI, but in the end must pass a technical feasibility review to be considered a valid entry.

The Building

For this contest, the location for this museum should not be a new building. We are looking at using an older public or community space which can be renovated and turned into a hands-on children's museum science exhibit for 10 to 16 year old students. One suitable building we have been considering for this exhibit is the Worcester Memorial Auditorium in Worcester, MA. Built in 1933, the Worcester Memorial Auditorium is a recently underutilized landmark of the city. It hosts a World War I war memorial spanning the front of the building and as well as being a landmark of art-deco style. The building has recently been placed on the 'Preservation Massachusetts' "Most Endangered Historic Resources" list. The basement is a very large space that can be easily renovated and turned into an underground lunar base. There is an old aircraft carrier elevator that is used to move large objects from the basement up to the back theatre (though it will need major renovations to work).

There is a back theatre that can be used as an entrance to the museum and then have the patrons walk down the stairs or ride down in the large elevator to the basement level. Unfortunately the back theater and the main exhibition hall share the same large stage as currently configured. There are not two separate stages that can be used for different purposes unless one is basically just showing a projection screen to an audience. The detailed floor plans and other documentation for the Worcester Memorial Auditorium will be made available to contestants.

Though this building is available for use in the design competition by anyone, entrants can choose to use any underutilized or abandoned public building that is within any city in the Northeast US, so long as it offers as much space over all its floors as the basement of the Worcester Memorial Auditorium (37,000 usable square feet). Remember that the building must support the look of a mostly underground lunar base from the inside when fully renovated. Some other recyclable buildings could include unused schools, auditoriums, factories or courthouses. If you choose to use a building besides the Worcester Memorial Auditorium, you must submit to the contest staff the building's floor plan to show that it has sufficient space for the exhibit, as well as any other details that you think would make this building a good home for an educational lunar base exhibit.

The Task

We are asking teams to design certain parts of this lunar base exhibit. There are three main parts of the exhibit, the mission control, the robot repair room, and the biosphere. In addition to these three main sections, there is also a list of other sections of a lunar base that you should choose at least two of to design. We want you to design each of these parts using the details found in the contest program. You need to submit a visual representation of your design for each part of the exhibit. We also want a written description of your design. This description should be between 3 and 5 pages describing your design and how fulfills the requirements outlined in the contest program.

Teams

The best teams for this contest will be those that are the most diverse. The ideal team would have an architectural major, and education major, an aerospace major, and one or two other engineering or science majors. Teams must have between two and six members. Ideally, each team should contain architecture major. If your team is unable to recruit an architect, another student with a strong enough artistic background to create the quality visuals required by this contest will suffice.

This is a student competition, for both undergraduate and graduate students. This not only helps to keep teams equal but also helps to facilitate team formation, since it is easier to form interdisciplinary teams on college campuses than it is in most places. WPI, which does not have an established school of architecture, will be forming technical teams and looking for architects from other colleges and universities to work with them. Other technical schools without architecture majors will be encouraged to do the same. A student team at WPI will serve as a clearing house to link technical teams with architects and interior designers.

Prize

There will be a cash prize awarded to the winning team in this contest. In addition, some schools may offer course credit for participants. This can also make a great addition to your resume.

Support

Architects will be provided to the teams as a visual production and support role on the team. SHIFTboston will be working to find student architects to pair with teams who need one. In the event that there is a shortage of student architects who would like to participate in this contest, SHIFTboston may decide to use professional architects. Do not organize a team with a professional architect without first obtaining permission from SHIFTboston. There will also be workshops put together by the support team that will give added information about both sciences of the moon and the design and educational application of interactive exhibits.

A support staff will be available to answer any technical or administrative questions that teams have with the contest. Because we want to make the lunar base exhibit as technically correct as possible in terms of the science involved, we encourage teams to contact the technical resources we have in place to ensure the accuracy of the information that they are presenting.

Conclusion

This contest is an integral part in the development of the space enriched science education at the primary, middle and secondary school levels and should help to provide a brand new and important kind of educational tool. Though this exhibit is considered an effort to produce the perfect field trip 5 years in a row, it is only one of the first steps in creating this air and space museum. However, this is the one with the critical local audience and thus the imagery to be created is important in making the case for the project and creating the support that will actually make funding this vision possible and the actual exhibit a reality. This contest is not only for the benefit of the schools and the city that hosts this proposed museum. We have made plans to insure educational and professional benefits for the participants in the contest and especially the finalists. They will all get to present their work at an AIAA conference. . Students should enter not only for the prize, but for the learning experience in working a team and creating a professional visual representation of a museum. As students, any type of project work is a worthy addition to a resume portfolio and something that potential employers will be looking for.

Appendix B:
Lunar Base Exhibit Contest Program

Design Considerations

Depending on which lunar base design one turns to for inspiration, the base is made of panels imported from Earth, a local form of concrete cast on the moon, or is carved out of the side of a crater into the bedrock and fiberglass tanks and tubes made from mostly local silicate materials are inserted into the manmade caverns. Metals such as iron, aluminum and titanium are also available. Glass sheets and bricks are also available and water is a good radiation shield. It takes 3-4 meters of piled regolith dust to approximately 90% of the radiation protection afforded by the Earth's magnetosphere and atmosphere. Hence, one wants to be underground and avoid glass domes and windows. Remember that your base is pressurized so the pressure is from the inside out, not the outside in. The problem would be to hold your dome down, as gravity on the lunar surface is only one sixth as strong as it is on Earth. There is also no wind or water to design around.

The Worcester Auditorium has many structural load bearing pillars in the basement. Oddly enough, this is realistic as the carving of chambers on the Moon in the crater side would have to be done so as to leave load bearing pillars if the air seal liner is to be flimsy fiberglass or aluminum. Cracked or impact-shattered rock would have to be reinforced with an iron pillar, which would not rust if it is outside the area with moist Earth-like air inside.

Materials

It is very expensive to fly building materials from Earth to the Moon (around $10,000 per pound). In order to keep the costs of constructing a lunar base down, as many of the building materials as possible would be extracted from the lunar regolith (soil). Many building materials that are commonly used on Earth, such as wood, would not be available on the Moon. Only important objects and materials that would be difficult or impossible to create on the Moon, such as electronics, would be imported from Earth. We would like to see you use as many local materials in your lunar base design as possible. Wood and other materials not available on the Moon can still be used as structural support in the exhibit as long as they are blocked from view by a local material. Since this is a second generation base it is possible to assume that the industrial capability to get building materials from local materials is in plane and even that there are some greenhouses devoted to growing fruit trees, bamboo and flax as well as a few other fibers, but use them sparingly. They are very expensive, but cheaper than imported plastics.

- Iron
- Aluminum
- Titanium
- Concrete

- Fiberglass
- Black or clear glass (sheets or bricks)
- Bamboo and other plants that can be grown in a lunar greenhouse

Exhibit Size

The Worcester Memorial Auditorium's basement has 37,000 square feet of usable space with 10 foot ceilings. If you choose to use another building for the exhibit, it should have approximately the same area, though not necessarily all on the same floor. The exhibit should be able to hold up to 120 students and chaperones; however the students would be split up into groups so each section of the exhibit only needs to accommodate 30 visitors at a time. This will allow for more effective flow though the exhibit and will decrease overcrowding in particular parts. There is an approximate size given for each section of the exhibit, which can be adjusted to fit your design as long as all of the sections fit into the floor plan and are large enough to accommodate the visitors. Most of these dimensions were adopted from the program from SHIFTboston's previous Moon Capital contest, which you may want to review for more details. Your submission should include a floor plan showing how each section of the exhibit will fit into the building you are designing for.

Information on the Worcester Memorial Auditorium:

http://www.worcestermass.org/uploads/e4/5d/e45d20af434b5b39764fcfafd37a0e49/Worcester-Memorial-Auditorium-Adaptive-ReUse-Study---July-2008.pdf

Exhibit Entrance

When visitors first enter the exhibit, they will be shown an introductory video before entering the lunar base. The Worcester Memorial Auditorium has a "Little Theatre" with 325 seats (plus 292 on the balcony) that could be used for this introductory video. If you choose to use another building, you need to add an entrance theater into your design, though it does not necessarily need to be as big. You do not need to actually design the entrance theater, as long as there is room allocated for it.

After the visitors finish the introductory video, they will enter the lunar base. They would ideally enter through elevator or "airlock" that gives them the idea that they are actually entering an underground lunar base. They should enter the exhibit into the Biosphere section's community area. From there the groups will split up to visit the other sections of the exhibit.

Mission Control

Ultimately the most important of the key exhibit features will be the Missions Control, or the Control Room and Communications hub, of the lunar base. This key area (in real life) would allow base operations managers to see and partly control almost everything going on at the base at one time. They would be concerned with key information about atmospheric conditions within the base, radiation from the sun and elsewhere, energy consumption and production, and the robotic processes, going on in and around the base. This would also be where the operators on Earth and monitors on the Moon passed control back and forth of given robots and systems.

The managers on Earth and the resident crew would efficiently run the base and since 5 people would be coming and leaving each month of the 60 person lunar base population, The actually pool of cooperating people handing off assignments and briefing is about 75 with another 900 staying on earth doing continuing assignment via semi-autonomous robots. Only about a third of the 60 people living on the Moon at any one time would be crew- running the base rather than running the gas mining and science operations that justify and actually pay for it all.

However, as part of the exhibit, the control room is actually the window that the students have on everything going on at the freight launch, in orbit, at the space launch base where the shuttles and hopper come and go from, on the progress of robotic operations doing exploration, mining ice at the bottom of the crater, extracting gas, metal and glass from the regolith, seeing what is in the sky, noting who or what is approaching, what the base looks like from outside and what is going on at the observatory on the far side of the Moon and in the greenhouse on the next level of the base. Surface operations can't be viewed directly, but things can come into the base for repair and reconfiguration. In short the students can experience a small part of the base core directly and all the rest, including building on to the base using robots they "see" from the Control room and monitoring center. However, we can send the image from any monitor to an assembly area to project onto a screen. To seemingly control the movements of a robot doing something on the surface or to communicate with someone out doing a task that needs information or tools they would have to be in the actual control room looking at a monitor with access to controls that seem to send signals "outside".

This will have to be large enough to handle at least a classroom of 30 students manning 15 stations (2 to each station) and set up so the others can watch what the two with access to the controls are doing. It is important that the control room allows one to see how people, robots and materials enter the case through airlocks among other things. The goal is to convey what it would really look and feel like to be in a base underneath the surface of the Moon short of changing the gravity level to 1/6th that of Earth. That will be a special challenge that is covers by a display a few students experience as they enter the base. It involves a frame, counterweights etc. and at best they will go to this area a few at a time to experience reduced gravity.

Located in the mission controls portion of the base might actually be the sole "lookout post" of the base, an actual observatory where someone can seemingly view the surface of the Moon, and see the Earth in the background. However, whether that is done using a Periscope or you enter a highly radioactive area for a total of 4 minutes to look out a window is up to the designer.

Also, this is where it is important to depict what it actually looks like to be living under the surface of the Moon. Mission control can be austere, but other parts of the human habitat would need to show that even though the base is underground, it can still avoid looking like a metal box, through the use of plants, and screens depicting outdoors.

The use of at least a few plants also allows discussion about the necessary chemical exchange between the plants and humans inhabiting the lunar base. The most critical points of interest for education include how the atmosphere is controlled, how the base is protected from radiation, the forces that are required to operate such a base (energy, gravity, pressure), and how the overall safety of the base is retained. That nothing is wasted and everything from exhaled air to organics recovered from feces is recycled. A closed system biosphere must be conveyed.

This part of the exhibits main features focus on the curriculum guidelines of the 5th graders, based on matter, forces (friction, gravity, magnetism and buoyancy), energy, light, magnets, etc.; however, it could also be used to demonstrate to 7th graders operating robots why there is a time delay in communication between the Earth and the Moon, based on the speed of light. How long the delay is communicating with an outpost on one of the moons of Mars could also be conveyed.

Key Educational Topics

- Atmospheric control
- Radiation protection
- Asteroid protection
- Biosphere Balance
- Production of materials(chemistry)
- Details of forces involved throughout the base
- Depicts the economy of which the base is part
- Overall hazards of the lunar environment that result in a new Man-Machine relationship

Suggested Size

- 4000 square feet
- Able to accommodate 30 students

Robot Repair Room

Robots are an essential element of a successful lunar base. They are capable of operating in the harsh lunar conditions that are dangerous for humans. Team Goddard envisioned a fleet of 300 semi-autonomous robots controlled primarily by operators on Earth. Constructed out of local materials, these robots would have several duties, including mining regolith for mineral extraction, searching the Moon's surface for rarer resources, constructing new base sections, tasks around the base such as tending to the greenhouse, and even building new robots. Most of these robots would be modular, making it easy to change a robot so it can perform a different task. The robots would mostly be controlled from earth, exemplifying the time delay in communication between the Moon and the earth. The robots would play a huge part in the base, as they are involved in almost every facet, from safety and production, to scientific exploration and general maintenance.

The robot repair room is the section of the base where the robots are repaired, reconfigured, and tested before being sent back out to the lunar surface. This will give the students a chance to actually handle the robots that they could already see from mission control. The educational value of the robot repair room also includes computer education, as the robots would continually need to be assessed and repaired or maintained. Robots would enter the robot repair room through an airlock from the lunar surface. Students would then have the opportunity to make minor repairs, reconfigure the robots for a new task, and test the robots to ensure they are working properly. When finished, they would drive the robots back into the airlock and pass control back to the operators on earth.

Key Educational Topics

- Delay when controlling a robot on the Moon from Earth

- Constructing robots out of local materials.
- Modularity in robots
- Dangers of the lunar surface
- Role of robots in a lunar base
- Suggested Size
- 4000 square feet
- Able to accommodate 30 students

Biosphere

The exhibit biosphere should represent the human environment that will be present in a 2nd generation lunar base. In this case, the biosphere would contain the living spaces, the greenhouse, and other habitat areas of the base. In the illustrations we provide, you can see other artist conceptions on how a lunar base would look and function. The purpose of the biosphere is to have a livable space that will be functional, but not bland, so that the base can be effective in creating a sense of home for the inhabitants. Living in a non-earth environment for an extended amount of time can adversely affect a person's mental functions, so accurately representing an Earth-like living space will help to alleviate that. Some ideas for this include incorporating greenery and art into the living spaces to accurately represent terrestrial life. The exhibit should offer a handsome representation of what these spaces look like. A bedroom, kitchen, bathroom, living spaces, recreation rooms, and working spaces should all be included in the exhibit. There should also be interaction built into these spaces. A video conference device embedded in a bedroom or similar ideas that could allow an astronaut living there to communicate back to Earth, or maybe even just watch their favorite sport. These small creature comforts would go a long way to maintaining the mental health of those working and living in the base.

At a lunar base, the greenhouse is a necessity for survival as food would be far too expensive to ship. In the current illustrations given, a greenhouse was built into the lunar base. However for our exhibit, the greenhouse would most likely be an off-site construction, allowing a full scale model to be created. One particular location we have researched is Tower Hill Botanical Garden in Boylston, MA. This is just one possible location where a lunar garden could be. In the permanent exhibit, there should be either a smaller version of the large greenhouse or some other way to convey the idea of a greenhouse to the students; such as one class at the mission control station observe another at the greenhouse, tending plants; even though the actual greenhouse exhibit is at a different location. Overall, every part of the exhibit should consistently be educational and scientifically accurate to the theme in place. Each year a different grade will come to the museum for a capstone to their curriculum topics for that year as listed in this program. Tower Hill has been told that the 6th grade curriculum will be heavily plant biology and thus after going to the main habitat as 5th graders the next year they are likely to be going to their site. They are thus to prepare for 1800 sixth grade visitors per academic year. They have offered to provide specifications for one of their green houses to be configured for this audience, but are open to the idea of building a new dedicated facility- underground- with mirrors directing light to the plants growing underground. Thus, it is acceptable for an entry to specify plans for new construction of the greenhouse element of the base- or just work within the constraints of an existing building at the Tower Hill site.

However, though this is actually a separate site it should be experienced by students in the base as just being one level higher in the base, seemingly just up a staircase or elevator from the habitat level. Those in the greenhouse should be in communication with those at the control center. The main base must be able to handle 1800 fifth graders in an academic year and another 1800 seventh graders (doing robotics) and probably 1800 eighth graders (doing chemistry) as well.

Key Educational Topics

- Exchange of gasses between humans and plants
- Why water is the key to life and animals are less important than plants.
- Mimicking climate zones
- Type of plants necessary to grow for a balanced diet of food,
- The plants needed to produce fiber and to clean and recycle the water
- The life of a lunar inhabitant in a subsistence garden village.
- Why some plants are to be found outside the greenhouse

Living Area

Room	Number	Size of Each (ft^2)	Total Size (ft^2)
Sleeping Cabin	6	100	600
Hygiene Facility (lunar bathroom)	4	30	120
Living Room	1	325	325
Kitchenette	1	85	85
			1130

Community Area

Room	Size (ft^2)
Communal Dining/Recreation/Assembly Area	4000
Exercise Room (with equipment for ⅙ G)	2000

Greenhouse (Off-Site)

Room	Size (ft^2)
Greenhouse (Off-Site, doesn't count toward the total space of the exhibit)	5000

Optional Exhibits

As well as incorporating these mandatory sections into the exhibit, at least 2 optional exhibits are required to be built into the museum. These exhibits should again be a continuation on the educational focus while still being interactive. The purpose of having these is to show that a lunar base has a wide variety of systems, spaces, and parts to it. Though the biosphere, robot room, and control room are an important focus of how people will live on the Moon, there must be representation of the multitude of other sciences, biology, and physics that are all integral in the existence of a lunar base. The following is a suggested list of ideas, but if you have any other ideas, feels free to submit them to the support staff to get them approved as part of the optional exhibit requirements.

Infirmary (Hospital)

A hospital-type exhibit could be used to teach about space's impact on the human body. This hospital should demonstrate the different health concerns (muscles, bones and fluid dislocation) that need to be taken into consideration when living with lower than Earth's gravity. Radiation risks as well as asteroid threats also need to be reflected in some way- possibly in how one plans a surface expedition. .

Ice Collecting

The water used by the lunar base will be collected from ice deposits located at the bottom of the crater that the base borders. The water only exists where there is perpetual darkness, otherwise it would evaporate and disappear. Handling the water is a tricky business but there is a 5th grade unit on Energy that goes into it in some detail and the students will be looking for something along the lines of what they have done as a scale model.

Material processing

In order to keep the costs of a lunar base to a minimum, as many resources as possible would be extracted from the lunar regolith. These materials are separated from each other using the differences in their melting points. After the ice is removed, each other element (aluminum, iron, titanium, polymers for glass etc.) is removed and stored for use.

Power generation

The power generation on the Moon should be mainly fission and solar energy (due to the perpetual light at the poles of the Moon). There should also be an experimental fusion reactor to continue the research and the development of fusion power, which would make use of the local fusion fuel (Helium-3) deposits on the Moon.

Spaceport and transportation

Internal transportation throughout the base as well as the transportation on and off Moon should be considered to be included. Transportation can range from a slingshot to a rocket and everything in between. On base transportation could just be shown, and not necessarily ridden. But the team Goddard design included molehill subways, glass roads, cable cars, tramways down to the crater bottom and "hoppers" (underpowered rockets that take the place of helicopters and airplanes when there is no air). There are also shuttles to take one into orbit and a "sling" to launch products (but not people) into space. Mass drivers could also be used for this cargo and freight launch purpose.

"Teacher in space" (communication and interaction with students on Earth)

A teacher in space with their own classroom populated by robots under the control of classes on Earth and could all see through the eyes of the robots was part of the Team Goddard vision. How to use moving cameras or cyber space mobility as in a video game to give the illusion of this situation is not hard to conceive. But where to put the teacher in space if they will not be interacting with the visitors to the base, but rather with the classes before they come to the base and after they leave is not clear. Clearly this involves figuring out how people control and interact with robots in 2069. Maybe cameras follow your body movements and the robot on the moon mimics your movements. This could also be broadcast to anyone around the region, country or even world promoting a regional or global effort in stimulating science education.

Animal research and zoological lab

As a part of the 'teacher in space', there would be a lab where there would be animals. No humans will be allowed to be born in low gravity before animals have gone through several generations of birth on the moon to see what happens to the bones and muscles. Would the Lunoids ever be able to tolerate the gravity or Earth? One of the few places in Worcester where children can see animals in close proximity is the Ecotarium. Perhaps the teacher in the space and the animal labs they run should be physically located there.

Exploring the Moon

Though we have pictures of all the geography of the Moon, physically exploring it can lead to many other discoveries. This could include a moon rover which may be manned or unmanned.

One especially popular activity with the 5th graders last year was planning an expedition to the lunar equator to check out a cave that might be the opening to extensive lava tubes. How to get there safely to carry out the mission was the challenge and we asked the children to consider the strategy of the turtle the frog and the sand crab as possible ways to get the people there safely despite the risk of solar flares.

Construction

Most of the buildings built on the Moon would have to be built out of the local materials, (regolith processing) as sending construction materials from Earth would be far too expensive. The construction would mostly be done with robots, before the human inhabitants would even be on the Moon. The Team Goddard concept was to carve into the crater side and insert fiberglass tanks to hold the air and water in the Earthlike atmosphere.

Radiation protection (keeping safe from a solar flare)

A solar storm could decimate the lunar base so radiation protection is incredibly important for the survival of the inhabitants. Regolith piled at least 10 feet deep is needed to stop 90% of the normal radiation levels. Some place much more secure is needed as a place to go during a solar flare. These rarely last more than 72 hours and usually pass in a shorter time than that. would be the easiest way to protect the base and the most obvious choice is to make the base underground with some part even deeper underground, but storm doors or water shielding on a temporary basis is also possible. However, this does not throw out the possibility of other types of radiation protection being exemplified. A bunker under a swimming pool or fish pond might suffice.

Other Necessary Facilities

The exhibit must be designed to be, or be in, a fully functioning building, and other areas different from the exhibits themselves must be built into the design. The building itself should be made to hold at least 100 school children at once, though they could be split up into two or more groups. Some needed areas that should be designed are:

- Restrooms
- Cafeteria (can be used as the biosphere community area as well)
- Administrative offices
- Janitorial and storage spaces

How you design or use these spaces is completely up to artistic interpretation.

The Educational Mission

The curriculum to be supported starts with a 5th grade chapter comparing the Earth and the Moon which follows a unit on the Earth stressing that the Earth's surface and weather patterns have much to do with how much water there is on the planet. They get to this point in the text in late November. It takes about 2 weeks to get 4 hours of science class and thus to cover a chapter. (Those that have science every day for a week then take the next week off and do social studies for a week, returning to science the next week.)

Naturally the comparison to the Moon stresses the lack of water, air and lesser gravity, but also points out that the Moon is made up of much the same materials as the Earth with a few key ones like carbon and hydrogen missing or in short supply,. The length of day and night, surface temperatures and cratered surface all get considerable attention. Unfortunately the text gives the impression of a desolate wasteland while in relative terms of space environments the Moon is actually resource rich, accessible and a major opportunity for economic mining of gas and metal resources that have great value when in space. The moon's modest gravity well means they are much more accessible to orbit than those on Earth.

The 5th graders cover about a chapter a week in their texts and the next several chapters on matter, forces, energy, light/sound and electricity are all to be covered with reference to the problems of living and working on the Moon. At the end of that unit of about 6 weeks (of science content (It will actually be in April) about-30 science classes in all) they are coming for the first time to your exhibit to review about 40 concepts related to those topics for the state MCAS math and science exam to be administered in late May.

It is a spiral curriculum so they will return as 6th graders to do a second day focused on biology- but that will probably be at Tower Hill unless you can work substantial greenhouse space into your design. They will be back as 7th graders for a day focused on chemical processes and return as 8th graders for a day focused on robotics. When they are in High School, as 9th graders there will be a day focused on Physics possibly getting into fusion and fission reactors, and as 10th graders the focus will be on Astronomy. As 11th graders there will be a design challenge and an integrative unit with a focus on the economics and psychology of space and the challenge of having communities of people not living on Earth.

By then they will have taken the MCAS as 10th graders and if they pass it they can graduate from HS. Thus, they can go on to advanced topics in 11th and 12th grade.
In this challenge we will focus on how well your facility can support the 5th and 6th grade curriculum, and since the biology unit will probably involve a trip to a different site- Tower Hill Botanical Garden- you should stress the general physical science goals of the students as they come for the first time as 5th graders and just make room for the rest.

The theme of the Earth and Moon comparison is why the Moon has a crated surface and why the site for the lunar base in the South Pole. Basically because the South Pole is where the water and solar energy are present. Be aware that the sun shines on the South Pole nearly all the time, but it keeps changing direction on a 28-29 day cycle. The situation at the equator is very different, 14 Earth days of intense light, followed by 14 days of bitterly cold darkness. Lunar conditions are to be conveyed, especially what you can do on the Moon that you could not on Earth. Why the water is at the bottom of the polar craters and how we know that is a major theme in the 5th grade readings (Bortz).

Matter- the lunar connection involves freezing, melting and boiling points of various substances and how they will act on the Moon as opposed to the Earth. Hydrogen (water), oxygen, helium, metals and glass can all be extracted from the lunar regolith and the metals separated by controlling temperature.

Forces (buoyancy, friction, gravity and magnetism) - The big message is how to think about the Earth as a big magnet and why the magnetosphere wards off solar radiation. Then we go into why most asteroids do not hit the Earth - (friction- they burn up coming through the atmosphere). Then of course one gets into the relationship between the size of the Moon and its gravity associated with its mass. Buoyancy we address by trying to figure out why a helium balloon goes up on Earth but would not do so on the Moon.

Energy- This unit is built around the problem of mining ice at the bottom of the crater and getting it up into the base separated from all the regolith dirt. It is to be melted in a black surface building at the bottom of the crater using parabolic reflectors of light on the rim of the crater to light up the black absorbent building. This becomes a kind of oven- but not too hot. We want to melt the ice, not flash it to steam. Once it is free of grit and dirt that settles to the bottom of a tank and one draws off the water at the top and put it out in the dark to refreeze into a big ice cube. It is then pulled up a ramp by a cable attached to a metal rod inserted into the water before it was frozen.

The energy question has to do with whether as you pull it up 4.2 km long 30 degree ramp, at what point is the potential energy in the mega-ice cube a threat to the ice house 3 km from the bottom of the ramp on the flat area at the crater bottom? If it breaks free and slides back down the ramp what will happen? What are the odds of this happening since there is a point at which the sunlight will hit the ice cube as it climbs up the slope on 14 out of 28 days (and it is direct intense sunlight at 212 f degrees on some of those days)? What happens to the mass of the ice and the friction of the ramps as the ice starts to melt in this zone? What will heat up first, the metal or the ice and what happens if the metal is conducting heat into the interior of the cube? The likelihood and consequences of a cable attachment failure at various points in its trip to the base are the point of the lesson. The risk assessment and possible solutions are the activity goals.

Light- Can we figure out how to avoid having to generate a huge amount of electricity to run grow lights in our underground greenhouse by getting the light to concentrate, turn corners and then diffuse to Earth levels suitable for plants in a chamber under 10 meters of Regolith?

This is enough to protect us from solar radiation at about the level of protection the Earth's atmosphere gives us.

Electricity- We will need some to power the base, even if not to grow plants. How best to generate it? What are the ways it is generated on Earth and which of them can't be used on the Moon? What is left and how do we use the solar or nuclear energy? Do we use it to boil water or can we directly convert solar energy to electricity with enough efficiency to be competitive with a boiler? What is the special resource to generate electricity exists on the Moon that does not exist on Earth? Helium-3 the fuel of the sun- which is a fusion nuclear reactor.