# • Lunar Base Exhibit Contest Management Team

*An Interactive Qualifying Project*

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# Abstract

The goal of this project was to create and manage a science exhibit design contest, whose target audience is student between grades 5 to 9. This exhibit is to have a Lunar Base theme circa 2069, which will be used to teach science concepts. Groups of students will be at this exhibit for about five hours, thus the exhibit will have between six to eight activity stations. This contest is to be sponsored by SHIFTBOSTON and American Institute of Aeronautics and Astronautics New England Chapter ( AIAA-NEC). SHIFTBOSTON specializes in the repurposing of urban buildings of historical interest and AIAA-NEC supports Science, Technology, Engineering and Math (STEM) education in the schools and seeks to foster a technically literate public that can appreciate the benefits of space activity.

Our team is third in a series of teams at WPI to conceive, define, publicize, schedule, recruit, and run this contest. Prior management teams were responsible for overseeing the creation of the architectural programs that SHIFTBOSTON requested of them. By the time our project started two architectural programs were, in principle finished. All that was left for us to do was publicize this contest through a website.

During our project we decided to support the WPI design team. This team didn't have an architect and was running on the original schedule of the contest set forth by the pervious team. From this experience we learned that the current state of the contest programs was insufficient to get a single team without an architect through the contest without additional support from the management team.

The outcome from helping the WPI team was that our team gathered materials and gave them feedback so they could finish their design. Through this process of supporting this team, we had to redefine the contest into two waves, a technical design contest and an architectural design contest. These separate contests fixed the major points failure of the pervious program.

# Introduction

This project is the culmination of the work done by teams at WPI over the last 4 years and ongoing efforts to renovate and repurpose the Worcester Auditorium. The new purpose for the Auditorium is based on an AIAA lunar base design contest co-winning entry authored by a team including WPI Professor John Wilkes and Worcester architect Dan Benoit. The original lunar base design contest, held in 2010, resulted in the selection of 'Craterville' as one of the co-winning entries based on elegant design concept, feasibility, and scientific accuracy. The envisioned use of the Worcester Auditorium is to serve as an educational exhibit and tribute to one of the great figures in Worcester's past, Robert Goddard. The newly renovated Auditorium would be repurposed into an historical exhibit on the upper levels, displaying the state of aeronautics during the life of Robert Goddard. The basement in this vision would serve as an educational exhibit based on the proposed design of a second-generation lunar base. The two exhibits are designed to depict a flashback to the time of the father of modern rocketry and an accompanying flash forward as far forward as the prior one took one back to the possible future of space exploration, mirroring the vision of Robert Goddard as he worked out the fundamental principles of rocketry that would one day enable manned space travel.

When the city of Worcester began considering the renovation of the Auditorium many things were considered, but in the end the city of Worcester approached Dan Benoit, an architect who had designed previous urban renewal projects in the city, and asked him to redesign the Auditorium for housing. Although Dan Benoit was opposed to that use of the Auditorium, he accepted the contract and produced a plan to turn convert it into housing. However, Dan Benoit remained opposed to the housing plan, and remained convinced there would be a better use for the building. The vision of converting the Auditorium into an historical museum and educational exhibit, flashing back to the time of Robert Goddard and flashing forward to the future of aerospace is closely tied to the Craterville lunar base design he worked out on a team of 8 people led by WPI professor John Wilkes. "Craterville" is ten meters underground on the edge of Shackleton crater, which is about 4 km deep and 21 km in circumference. It is also very near the south pole of the moon. In the bottom of this crater is water, probably in the form of ice. Water is only available on the moon in areas of perpetual darkness. The angle of sunlight at this location keeps it from reaching the bottom 2/3rds of the crater. However, at the top of the crate r this spot also has continuous sunlight coming in at a low angle. It is an exceptionally good location for agriculture and the use of solar power as well as being where the water is.

The base was designed as a second generation base. This means that infrastructure in a crude temporary base was needed to build it 90% out of local materials. It 'was" completed in the year 2069 after 15 years of planning, 10 of those under construction. It could be expanded so as to house 6000 people and 30,000 robots in about 60 years. In 2069 it houses 60 people on one year deployments to the moon. However, the main labor force is 300 semi autonomous robots operated by 1000 people in 3 shifts on Earth. It's an agricultural village married to a gas mining facility that can pay for itself and feed itself.

Its' economic mission is to mine oxygen out of the lunar regolith to keep orbiting fuel depots supplied with LOX (liquid oxygen). The other gas of interest for the future was Helium-3 a fusion reactor fuel deposited on the moon, but not Earth, by the solar wind. It is the fuel of the Sun and by 2069, near the end of the oil era, developing fusion reactors has become a national priority. Given such reactors, about 26 tons of Helium-3 would be needed to supply the USA with enough electricity for a year at 2010 rates of consumption. Of course, 50 years later energy use would be far more efficient so increasing energy requirements could easily be met. There is an estimated 1000 years of fuel available on the moon at current rates of consumption by every nation on Earth. The question in 2069 was which nation or nations would control the Earth's new energy resource? Thus, a new space race was underway by 2050 and Craterville was in a very strategic location.

The projects done at WPI over the past 4 years, sponsored by the AIAA-NEC, have focused on the development of lunar base themed educational activities to supplement the 5$^{th}$ and 6$^{th}$ grade public school curriculums in Massachusetts. The core concept of these projects was to use once a week activities related to living and working in space to illustrate and apply the concepts taught in the classroom that week. These teams were given a $50 budget for materials per chapter in the standard science textbooks used in the classrooms. They were also given a budget of $500 to spend on a field trip for the classes they worked with during their projects. These teams developed activities for an average of 3-6 chapters each year. Over time a pool of activities that were supported by both the teachers and the students was developed. These programs set the stage for future work to be done applying this supplementary program to chemistry, robotics, biology and more in the 7$^{th}$ and 8$^{th}$ grades.

WPI students considered this lunar base concept a playground for teaching about the Solar System, Matter, Energy, Electricity, Light and Sound, Forces and Motion (Chapters 13-20 in the 5$^{th}$ grade text). Soon there was an activity using wax developed around a discussion of the melting points of the various silicates and metals in the regolith that were needed to construct the base 90% out of local materials. Aluminum, iron, steel and titanium, even some platinum and chromium were available but no copper, or silver. Water, glass bricks and fiberglass were also available. This spawned two activities. One was on basic construction materials focusing on iron, titanium, glass and water.. Then there was another one involving circuitry, conductivity and photovoltaics on how to power and wire the base given the limited number of conductors and insulators available to work with and the total lack of any fossil fuels, waterfalls or wind.

The various forms that glass could take came up as the search for insulators proceeded with no rubber or plastic available.

The challenge of getting water separated from the regolith and up the 30 degree slope of the crater was the theme of another activity. Then there was the challenge of how to get enough light for agriculture into a greenhouse that was 10 meters underground due to the need for radiation shielding, Activities covering friction, gravity and magnetism were also devised for 5th grade. Motion was deferred to 6th grade. However, it was surprising how similar the concepts in the 5th and 6th grade texts were.

Though the 6th grade team did some assessment, review and new illustrations of concepts covered the year before (where less than 50% of the class had mastered a concept), they also moved on into new territory. Biology, specifically botany, was tackled in 6th grade as the class turned its attention to just what would one grow in a lunar greenhouse? This would not just be about food; it was also a way to get access to rubber and feedstocks for plastic.

This unit involved a trip to the Tower Hill Botanical Garden to get an idea of the scale of the facility envisioned. Once it was clear that they had to construct and maintain a biosphere that circulated air and water, the students got an idea of how central the greenhouse was to the success of the enterprise. They also considered what carbon dioxide levels were best for different kinds of plants, discussed temperature ranges and the pros and cons of hydroponics versus trying to convert regolith into soil (given the success of Tower Hill in growing large plants in pots). The staff at Tower Hill and a botanist who is a WPI graduate were all questioned about how to keep plants alive indoors.

Consideration of the actual plants to be grown involved a nutrition lesson focusing on a vegetarian diet other than the two meats available: vegetarian fish and worm meatloaf. The role of worms in accelerated composting was examined. These meat alternatives provoked great interest the best vegetarian sources of protein, such as quinoa and soybeans. Soon the 6th graders were fairly conversant with the pros and cons of all 11 major staple plants and considering the case for cattails as an unusual but highly productive source of starch, protein and other nutrients. Sources of protein and vitamins were then brought into the discussion to balance the diets based on different staples.

Finally the students took into account what else they would need on the moon that can come from plant sources and soon had a substantial list including things such as textiles, paper, glue, rubber, plastic, paint and dye, medicine, lubricants, bamboo and wicker for furniture, padding for pillows, etc. Then of course there was the question of plants that were of interest for multiple reasons, such as latex derived from sunflower or cassava plants rather than rubber trees. They were closing in on a short list of plants with all parts useful and that could be completely recycled when they ran out of time for this activity.

The final unit was on experimental design, and there was confusion about demonstrations versus experiments. Clearly this experiment would involve plants and things that affect their growth. Water quality, carbon dioxide levels, light patterns, temperature, compost and nitrogen fixing plants as a resource for other plants and the question of how to pollinate without insects all came up for consideration. In the end the class wanted to do light, carbon dioxide and water quality. Could plants get too much light? Could the water be too clean? How much more carbon dioxide than there is in Earth's air currently did it take to" have the effect of "dumping fertilizer" on C3 plants?

In the end the team that wanted to go ahead with the light pattern study and 3 students said they wanted to take it to the science fair enough to come after school to prepare. The AIAA NEC reviewed the question and decided that they would need hydroponic plant incubators to reach the pace of plant growth needed for a lunar base- and finish the study in time for the science fair. NASA has approved some small ones for growth rates ten times as fast as in soil on Earth. They cost about $62.00 each. The students said they needed three to do an Earth control and represent the lunar pole and equator. With chemical nutrients it was about $200.00. This budget was approved, as sort of a spinoff of the $650 field trip for 55 sixth graders to Tower Hill Botanical Garden to learn about plants and greenhouses. The teacher cared less about the science fair than the dry run presentations in the class where her students finally saw a fully worked out experimental design complete with control variables and control group. She stressed which was the independent and which the dependent variable. The class finally for the first time understood photosynthesis as well. The science teacher was thrilled.

Hence, this is part of a $900.00 AIAA curriculum enhancement experiment at this point. On the other hand, the field trip was wildly popular and the rest of the materials are reusable in future years. This Science Fair experiment may be unique in that the mastery of lunar conditions and plant requirements grew directly out of classroom activities tightly tied to the text in use. The students needed no outside research beyond 15 weeks (over 2 years) of oral in-class briefings to set up the experiment. They do not know where all the speakers and interviewees got their materials and they think much of this information is common knowledge given how they encountered it.

It was not until some of the plants died that they had to consult the literature to consider whether the cause of their demise was too much light- or too much light generated heat, The student investigators expected to see differences in rate of growth, not survival rates. There were other surprises as well, especially in the related sprouting study. A replication study measuring heat levels indicated that in a 75 degree F classroom, the plants were experiencing 100 degrees F when the grow lights were on under a box- which was intended to block all other light sources. This experiment inspired the contest team to consider whether something substantial could be done in the main lunar base exhibit, despite being underground and limited in space. It might be possible to set the stage for the Tower Hill Field trip in one station for 5$^{th}$ grade and spin it off of the greenhouse light question.

Originally the goal of Brian and Sarah's project was to manage a contest where teams of college students would design an educational lunar base exhibit to be installed in the basement of the Worcester Auditorium. This exhibit was envisioned as the ideal field trip destination for 5$^{th}$ grade to 8$^{th}$ grade students, and was intended to accompany plans for the historical exhibit on aerospace in the time of Robert Goddard that would be on the first floor. However the rules for the contest were not completed, and the material required to publicize the contest was not fully prepared. Therefore the goal of our project became instead to finish preparations for the contest so that it could be run as part of a future project. As part of preparing for the contest, we planned to decide how to publicize the contest and prepare material for a website intended to recruit teams to enter and get the attention of potential sponsors.

There was also a design team, advised by Professor James Dempsey, which we had expected to enter the contest on the original schedule. Given the changes to the contest itself Brian and Sarah decided to give them support during our project as a trial run or pilot study for the contest itself. In order to support this team we needed to gather the results of previous projects done at WPI that were relevant to the Lunar Base Exhibit itself and the design of a lunar base in general. Supporting the team became one of the primary focuses of the project, as it became clear that their experience could be used as feedback to improve the contest as a whole for the following project, which was intended to manage the actual design contest.

Professor Wilkes recruited Andrew McKay for a project with the original intent that he would publicize and manage the design contest during C and D terms of the 2013-2014 academic year. Ultimately the experience of the concurrently running design team would alter the contest sufficiently that Andrew McKay would join Brian and Sarah in their efforts to prepare the revised contest rules. The contest itself would have to be run at a later date. Andrew would go on to continue work individually to finalize what would go on the Website after Brian and Sarah had finished their parts.

## Contest Overview

This contest arose from a previously held architectural contest run by the AIAA and SHIFTBOSTON in 2010. This contest produced various Lunar Base designs, the top ones being from Team Goddard of Worcester) headed by John Wilkes of WPI and Daniel Benoit as the architect) and Tom Schmit of Hong Kong. Team Goddard's design Cratersville, which could feed and pay for itself was used as the conceptual inspiration for this contest. Schmidt's drawings and artwork set a standard that was very useful in improving the Team Goddard artwork and depicting key parts of a South Pole Lunar base. Comparison of the two bases became a standard 5$^{th}$ grade activity. This outcome also allowed for the creation of the contest that Sarah Triplett, Brian Scholwin, and pervious WPI students have worked on creating.

The current version of the contest is split into two sections, a technical design contest, and an architectural contest to follow. In the technical design phase of the contest entries of an individual to a full team of four to six people will design activity stations that will be used in the futuristic part of a larger Air and Space Museum, as part of a Lunar Base exhibit. The architectural portion of the contest will take activity stations from a pool of educator approved stations and design this part of the exhibit to look and feel like Lunar Base.

The idea is to get an exhibit that would be an ideal field trip destination for children in the 5$^{th}$ to 8$^{th}$ grade when they start to learn about the science and technology in their texts, that would also go into building, maintaining, living, and working in a Lunar Base environment. This contest has already been approved in principle by both AIAA and SHIFTBOSTON, the sponsors of the contest held in 2010, which adds to the credibility of the contest.

The intended goal of this contest is to get imagery. The currently abandoned Worcester Auditorium is continuing problem for the City of Worcester, and ideally these images produced by the contest could be used to spark a debate on the use of the Auditorium. Evocative images will help justify renovating the Auditorium into an Air and Space Museum. The first floor would be a Goddard exhibit that is also being designed by student team at WPI with the help of Dan Benoit. The basement will be a Lunar Base exhibit, which is an ideal location because it has a cavernous feel to it.

## Visiting the Worcester Auditorium

Previously the Worcester Auditorium was used for many purposes. It has been used for various theatrical purposes, is a World War I monument, and has been the site of Holy Cross Basketball games. The most recent use before it was abandoned was to put the Juvenile court in the basement of the Auditorium.

The Worcester Auditorium was already approved by pervious teams at WPI as a site which could be used as an ideal location for a Lunar Base exhibit.  The Mars Foundation asked if half of the floor space that would be used for a Lunar Base exhibit could be used for a comparative and contrasting Mars Base exhibit. The educational case for that was rather good.  In order to better understand as to why the site was so attractive for space base mockups, Brian Scholwin, and Sarah Triplett visited the Auditorium.  This trip was set up after the pilot run technical design team asked for a tour, and Dan Benoit and the head of the Mars foundation could also be present. This was a good idea and provided a better understanding of the current state of it and to again confirm that this is indeed an ideal location for a Lunar Base exhibit. The question was how later participating team could get the benefit of a similar experience.

When entering the Worcester Auditorium it was obvious it hasn't been used in a long time, and that it was necessary to have major renovations to get it in working standard for use by a public audience. This is true for all areas of the Auditorium and it is clear that a project to renovate such a building would be around fifty million US dollars. However, the part in the best shape was the basement which had been used as a juvenile court.

When we went into the basement of the Auditorium we could understand why pervious teams liked this location. The basement gives off a cavernous feel, with no windows, and no natural light. This is ideal for the a Lunar Base environment as there would be no natural light due to hazards cause by radiation from the sun with no atmosphere on the Lunar surface, and the cavernous feel adds to the feeling that this area could actually be a Lunar Base.

The basement also provided excellent areas which could be used for certain exhibits. For example in the center of the basement where the juvenile court use to be there is a courtroom which could be repurposed into a command center exhibit with minimal renovations to the actual room. The program teams last year had a similar tour and concluded that the command center should be in the middle.  That decision will have to be reviewed by the architect now that the space is to be divided into two base exhibits.  It is not clear that it can be the control center for both Mars and the moon- especially if groups are visiting both exhibits at the same time.

## Supporting the WPI Design Team

### Setting up Meetings with Team Goddard and Paula Proctor

One of the first things we decided upon was to support the current design team, to see what they needed. This was done by Brian reaching out to the team to see if there were any questions that the team had during about key points they needed to address in their design.  They requested a tour of the building and meetings with key members of the original Team Goddard who made the 2010 design that this contest was designed around.

Brian Scholwin was responsible for reaching out to Team Goddard and Paula Proctor. The members of Team Goddard that the WPI team met with included Marc Andelman, Brian Moriarty, Dan Benoit, and Bruce Mackenzie.

These meetings, or informal talks, were organized and video recorded by Brian. To get in contact with them Brian sent out an email to Marc Andelman, Brian Moriarty, and through Professor John Wilkes an email was sent to Paula Proctor. Wilkes decided that the best way to get in contact with the pilot run design team was through their advisor, an expert of the history of the Auditorium. An email was sent to Professor James Dempsey the design team's advisor, to get the contact information for all members of the design team.

Once he got into contact with them he was able to set up attend their meetings and have separate meetings with the student members. The design team and others attended these meetings with the experts brought in to brief them. During these meetings students would listen to a presentation given by one these experts. These presentations were about their field and unique ideas or experience that they brought to the table in Team Goddard. They were also allowed to ask questions during these talks to help get a better understanding of what their ideas might support as an educational activity.

## Marc Andelman

Andelman is an expert in Botany and water purifications. We recruited him to talk to the WPI design team about what his experience in Team Goddard when it came to conceptualizing the Greenhouse for a Lunar Base that both feeds and pays for itself.

His talk was to help the design team think about what should go into a Greenhouse in a Lunar Base setting. In addition he explained to them why a swamp like setting would be ideal for part of the lunar base greenhouse. He presented a swamp setting as being the best natural water filtration system. He went into the difference between C3 and C4 plants, and that the C3 plants should be put into a $CO_2$ rich environment. He also gave an example of a plant that should be in the Lunar Base, which was the Cat Tail.

The WPI Team was impressed by what they talked about with Andelman. This is evident in the fact that they decided to put a greenhouse in their actual design when they did not need to do so. . The main reason they did this was to demonstrate the difference between C3 and C4 plants in their exhibit, in addition to air and water recycling. It was clear that Andelman made this team feel as if the greenhouse was too important to leave to anyone else and they decided to put a sort of scaled down greenhouse station into their exhibit along with the illusion that there was a large greenhouse behind a wall, closed to them because the air was not breathable by humans.

## Brian Moriarty

Moriarty is an Interactive Media and Game Design professor at WPI, who helped set up the Christa McAulliffe Center in Framingham, MA, when it was being designed. When this Center first was built it initially had a Lunar Theme Though now it depicts a Mars crew exchange mission. With this additional background he was an ideal candidate to talk to the WPI Team about how they should set up their exhibit

Moriarty talked to the students about the Christa McAuliffe Center, which is a popular site for field trips for schools in Massachusetts and is usually 2 years booked in advance. This center is located in Framingham, MA. Moriarty described about STEM field trip destinations and how no two were the same. This idea led into his main discussion, on how we could use video and the internet to connect these STEM destinations to one another making a better experience for the visitors. He also went into a new type of technology known as telepresence which would use the same concepts but gives off a more realistic feel.

This is another person that the WPI team really followed as they chose to follow the same model as the Christa McAuliffe Center, where students in a $5^{th}$ to $8^{th}$ grade range would come once during their middle school years and all grades would get the same set of activities with only modest changes to change the $8^{th}$ graders more than the $5^{th}$ graders. The other program which they could have chosen would have been to follow a spiral curriculum in which the students in the school district surrounding the exhibit (Presumably WPS) would came back year after year to get totally different programs at each grade level gauged to their changing curriculum goals.

However they didn't take all of Moriarty's ideas. This was clear when they didn't use their "Mission Control" exhibit to import images from other STEM destinations, or connect with it in any of the ways that Moriarty presented as the way of the future in science exhibits.

## Dan Benoit

Benoit is an architect who is well known by both the City Planner and especially a former City Mayor of Worcester now in state office. He was also responsible for the reshaping the center of Worcester, which also included repurposing the Worcester Auditorium for housing purposes. However he wanted to make this building into a treasure like it was in the past. Being the architect that designed Cratersville for Team Goddard the idea of using the Auditorium's basement as a Lunar Base Exhibit, and the first floor would be used for a Goddard exhibit, where the theme of this museum would be "flash-back, then flash-forward". To get the city to agree to this he endorses the idea of getting imagery for the exhibit through a contest.

What he presented to the WPI design team was some of his ideas for redesigning the center city and the Worcester Auditorium as a way for the WPI team to get an idea of what he does. This led to many questions about his ideas for the first floor of the auditorium. By the end of his meeting with the WPI team he briefly went over his work on Team Goddard and what his experience was with that.

However, overall the WPI didn't get anything from this meeting that they used in their exhibit. This is shown by their initial lack of a human habitat and a rushed version of the human habitat in their final version of their exhibit. This is mostly due to their interest in his ideas for the first floor of the auditorium, which they focused most of their questions on. The result of this was the WPI Team not receiving information on designing a Lunar Base from an architectural point of view, which could have helped them because they didn't have an architect on their team.

## Bruce Mackenzie

Mackenzie is an expert on Mars, and is the founder of the Mars Foundation. He is a MIT graduate, technical expert, and has an architectural background. He doesn't believe that there should be a Lunar Base, due to the conditions on the Moon, for example the lack of water on the Moon, and a tough environment for plants to survive on the Moon. However most of the innovative technologies that were put into Cratersville were his ideas. These include the "lunar sling" and "water airlock", and he also came up with the idea of Cratersville feeding and paying for itself, and figured out what the base should be made out of which was spun fiberglass.

In his talk with the WPI team he talked about the innovated technologies in Cratersville. One the technologies that he presented was a lunar sling that could get cargo into orbit around the moon so that a ship could pick up this cargo without having to land on the moon itself, or you could have a system of slings and bring the cargo to low earth orbit without consuming any fuel. This idea also went into how we could make interstellar trade possible, as the Moon has resources that could be used on Earth and Mars, Earth's atmosphere has materials one can use on the Moon or Mars, and Mars likewise has materials we could use on the Moon and Earth. The other technology he introduced to them was the water airlock. This was not originally his idea but the need to reduce the loss of Earth-like atmosphere from the base every time you open the airlock can be mitigated if the astronaut is "hugged" by something that will block the air release. Hence, you pass the person in a space suit through water and then recover most of the water on the other side before they actually go out on the lunar surface. What made this idea interest in to the station design team was the pressure differential between outside and the base interior produced a J shaped tube of water with the long leg 50 meters in length and passing through the rest of the base. It was a great visual and introduced some interesting concepts from physics. Mackenzie also illustrated some of the differences between a Mars and Lunar Base. For example he illustrated that because Mars had an atmosphere windmills and airplanes are possible on Mars, among other things.

Mackenzie greatly influenced what the WPI team put into their exhibit, when they put an exhibit to demonstrate how the water airlock would work in one of their activity stations. This showed us that the WPI Team took a huge interest in Mackenzie's innovated technologies making the technologies behind a Lunar Base the main focus of their exhibits, rather than building a Lunar Base like environment.

## Paula Proctor

Proctor is a former Science curriculum coordinator for the city of Worcester and was the Principal of two schools, including Elm Park School as well. She is an education expert that was on the group that selected the Worcester text (she voted against it) and served on state level committees reviewing the Mass. state science frameworks that are the basis for the MCAS test.

She was in a position to make it clear what the teachers would be looking for in deciding whether and where to take their classes on Field trips. When she became a principal at Elm Park (Middle School), which is located right down the street from WPI she learned of the concept for this exhibit and was intrigued. She offered her school as a curriculum development and testing site. She remains a strong advocate of this science enrichment program in general and the idea of a simulated lunar base exhibit in particular. Though retired as a principal, she still holds influence in the Worcester Public Schools and the State of Massachusetts. Currently she is part of the educational debates for the Massachusetts Comprehensive Assessment System (MCAS). She also supports the idea of a spiral curriculum that would be used in the scenario where the students would come back to the exhibit year after year.

The WPI design team took the information from Proctor and decided to justify their design through what was in the frameworks and likely to be on the MCAS. This was done with the idea that it would be more desirable for educators to take their students to their exhibits as it would help prepare them for the MCAS. While this is encouraged in the rules this also limited their vision of the larger purpose of the education program, m in a lawyerly fashion the justified their stations with references to specific passages in the Framework, but missed the large perspective of the teacher trying to cover the entire concept in the text. It also made making the whole look and feel like a lunar base largely irrelevant. The exhibits were spotty in their coverage of the 5$^{th}$ grade curriculum which was to go with the exhibit. This experience led to rule changes to warn of contest participants of the reviews the educators were likely to give such an exhibit, even though everything was justified in terms of the State Frameworks.

# Results of these Meetings

What these meetings did was give the design team an idea of what a Lunar Base should have and its environment. This was clearly represented in their design of the exhibits, examples of what they wanted to explain from what they learned during these meetings was clear when they made an exhibit for the greenhouse on base and the water airlock, which we mentioned by the people that they talked to.

We also saw that they took what these presenters said seriously with their stress on focusing the exhibits to teach what was required for the MACS, which was explained by Paula Proctor the education expert. While this is an important aspect to the contest, it made their report seem as if there is very little emersion into an actual lunar base environment.

This decision that the WPI design team made when it came to their exhibits in our opinion help back the potential of their exhibit, as they focused too much on staying in the parameters of the MCAS, and they initially left out an example of where the people who would be stationed in an actual lunar base would stay, which ties into the emersion to the lunar base environment.

Another problem with their exhibit lies within the “Mission Control” or “Command Center” exhibit. The WPI team decided to design it around the concept of a communication center rather than the place where everything is decided, or controlled from, or a place where problems around the base could be solved. Now while the actual situations that could be used in a “Mission Control” exhibit are almost limitless, we can see from the WPI design team that most teams would not consider to add these type of situations that students could find both entertaining and educational anywhere in the report.

This led us to consider revamping some of the rules and regulations so that design teams would start to consider adding situations that the student will need to solve in the actual design of the “Mission Control” exhibit. Now for the timeframe of our project we didn’t have time to dedicate to revamping the rules and regulations to accommodate this new development, due to the late submission of by the next Lunar Base Contest Management Team, which is currently Andrew McKay, whose project ends in A term 2014.

Lastly what we noticed is aside from the revolutionary “Water Airlock System” and certain details about the green house, i.e. the use of C3 and C4 plants, the design team did not mention anything that was talked about during their talks with team Goddard. This again could be the fact that this design team focused too heavily on meeting the educational requirements for the MCAS that they decided that these technologies have nothing additional to teach the children for the MCAS.

## Expansion of and Changes to the Contest Rules

One of the initial goals of this project was to evaluate previous teams' plans, proposed programs, and scenarios for sections relevant to the rules of the design contest. These sections were to be evaluated and if necessary incorporated into a new rules document for the contest that would also be posted on the contest's website. Initially based on the work done by previous teams to prepare for the contest there was only one update to the rules required. At the conception of this contest, the exhibit was intended to make use of all forty thousand square feet in the Worcester Auditorium's basement. This was later changed to allow the exhibit use of half the basement's floor space in order to accommodate a parallel Mars Base exhibit on the other half of the basement. This change to the space available for the exhibit was incorporated in to the contest rules. The Mars Base exhibit remained an independent endeavor, and there were no further alterations to the rules necessary. The Mars Base exhibit was also being developed and required no additional support from our team, and therefore the updates to the rules were expected to finish quickly.

However the revision to the rules to accommodate the Mars Base exhibit prompted us to fully review the rules to ensure they were still consistent with the intended goals of the contest. One of the first deficiencies discovered in the rules was the requirement that the Lunar Base Exhibit be located in the basement of the Worcester Auditorium and that the greenhouse station be located at the Botanical Gardens at Tower Hill. The major concern with the Tower Hill requirement was that Tower Hill was unable to guarantee it could meet all the requirements of fulfilling the role of the greenhouse station. We also decided the requirement that the exhibit be designed specifically for the Worcester Auditorium basement was a concern because the city was actively searching for suitable alternative uses of the Auditorium itself, and its use could not be guaranteed. Additionally, we decided these restrictions were inconsistent with the intention that the contest be open to the students throughout the North-Eastern United States. The requirement of a location in Massachusetts gave teams nearby an advantage over teams from schools further away such as New York, Maryland, or Maine. The teams further away could not be expected to be able to visit Tower Hill or the Worcester Auditorium. Conversations with the concurrently running design team indicated that visiting these locations was considered a valuable experience. The team was able to determine the exact conditions of the two locations, as well as exactly what resources were available and what the specifics of the locations design was.

Adjusting the rules to allow teams to use alternative locations for the exhibit and the greenhouse also prompted us to evaluate the extent to which we wanted to constrain the design teams. This issue would go on to be one of the core focuses of future changes to the rules, and our resolution to this question was that we desired to allow entrants as much flexibility as we could while still directing them to produce entries that met all the goals of contest. Initially we decided that the location of the Lunar Base on the moon that the exhibit would be based on should be open to alternatives as well. Although the proposed lunar base the contest is founded on is located in Shackleton Crater in the lunar South Pole, there are several valid reasons to consider alternative locations. Recently scientists have discovered craters at the lunar North Pole appear to have a higher concentration of ice water than those in the south. Additionally, the possible existence of a large cave near the equator in the Marius Hills provides an intriguing location for the base because of the possibility of preexisting radiation shelter in the form of lava tubes. Although we ultimately decided to prioritize flexibility the ‘Craterville’ basis for the project made it prudent for us to restrict the entrants to polar locations for the base.

The results of these decisions were incorporated into the contest rules and allowed teams to use an alternative location for any combination of the greenhouse, the Lunar Base Exhibit, and the Lunar Base location on the moon. In order to use an alternative location teams were required to submit a request explaining why their alternative was suitable. The requirements for an alternative location for the Lunar Base Exhibit were twenty thousand square feet of floor space; that the exhibit itself is located in a part of a building that is underground; and that the building is underutilized or in need of renovations. The requirement for an alternative location for the Lunar Base itself is that the location selected can provide all the same resources that a base located at Shackleton Crater could. These changes to the rules allowed contestants to be more imaginative while designing their exhibit, but still provided a basis on which to build for all teams. This section of the rules was later revisited in conversations with Prof Wilkes and was revised further to more accurately reflect the desired alternatives to the Worcester Auditorium.

In addition to these changes, further review of the rules after the concurrent design team had finished produced several insights into the ways in which the rules and contest design in general might be improved. These insights would ultimately lead to the separation of the contest into educational and architectural sections, the introduction of a Control Center requirement, an update to the Greenhouse rules, and the addition of rules to allow single station entries. The overall intention of these changes was to guide teams to produce entries that more closely aligned with the original intentions of the contest designers.

One of the primary results of the concurrent design team’s experience is that it was difficult for a team of students designing the educational components to find an architect with which to work. This realization prompted us to evaluate whether or not an architect was needed in the group in the first place. Ultimately we decided that in order to finally make the Lunar Base Exhibit design viable an architect would need to be involved in designing it. However in order to allow as many teams to enter as possible it was decided that the contest would run in two stages.

The first stage would be open to teams of any discipline(s) and would be focused on the educational and thematic components of the Lunar Base Exhibit, rather than the specific details of actually incorporating the exhibit into an existing building. This first stage would consider the feasibility of exhibits proposed however the entries will be evaluated mostly on the quality of the educational stations and on their use of the Lunar Base theme in the exhibit. After repeated conversations with Professor Wilkes and discussions to decide the details of this change, the rules were updated to reflect the new focus of the first design contest. These changes removed the only major restriction on team composition and are expected to allow more teams to submit entries to the contest than would be possible with an architect required on each team.

Accompanying this rules update was the creation of a set of rules to govern the architectural section of the design contest. It was decided that the architectural design contest would run after the educational section of the design contest and would draw from the pool of the work done by the best individual and complete team(s) as a basis for designing the specifics of the larger exhibit. The architects are expected to design the final exhibit in a practical and realizable manner while still giving the whole exhibit the look and feel of a lunar base. By separating the educational and architectural portions of the contest the architects were also given more options to use with regards to other contest entries than they would have had working as part of a team. The architects would also have access to the judge's reviews of each entry, which could allow them to improve on a concept which had been poorly executed but well received or make other similar alterations.

Another major change to the rules that resulted from managing the concurrent design team was the inclusion of the command center requirement. Discussions with Professor Wilkes and with previous teams revealed that a station based on the lunar base's command center was considered extremely important to the lunar base theme. This station is important because it allows the design teams to show pieces of the lunar base's larger contest and the infrastructure needed to justify and support its existence. Elements that would otherwise be invisible or ignored can be depicted or monitored in the command center without physical reconstruction. It is also the part of the base that is capable of tying all the other stations together, and because of the infrastructure it is capable of showing it allows teams to cover educational topics that didn't fit in any other section. Finally the command center is also important because it is the focal point of one of the revenue streams contest entrants are encouraged to protect.

The command center requirement was added to the rules after these discussions and it specifies that any team submitting a full entry must submit a command center station as one of their six required educational stations. To provide teams with a starting point for the command center a supplemental document detailing some of the lunar base's infrastructure was created. This document included everything from monitoring an expedition traversing the lunar surface to orbiting fuel depots. Teams were also given a baseline requirement for the command center and were encouraged to add any additional infrastructure or imagery they felt appropriate. These specific requirements were a significant departure from the deliberately general approach used when writing the rest of the rules and were a major point of discussion. Ultimately it was decided that the command center was a crucial part of the design of the exhibit and that by giving specifics for it teams could be guided in the design direction intended for the contest. The limited vision of the control center developed by the WPI design team was on of the key factors in deciding to expand the control center requirement.

In addition to the command center requirement another exhibit requirement that was a repeated point of concern in discussions with Professor Wilkes was the greenhouse station. Originally the greenhouse station was intended to reside in the Botanical Gardens at Tower Hill. This station would serve as a separate field trip destination for students in 6th grade instead of a trip to the Lunar Base Exhibit. Brian and Sarah found that the 6th grade curriculum was a good fit for the topics that would be taught at the Botanical Garden. The garden provides a good opportunity for teams to teach the concepts of photosynthesis, biospheres, botany, and nutrition. As the rules were originally written, each team would be required to choose to either include a greenhouse station as one of the six required stations in their Exhibit, or they would be required to base their greenhouse station on the gardens at Tower Hill. In both cases teams were expected to provide exposure to the staple plants that would be available in a Lunar Base to teach many of the topics present in the 6th grade curriculum. This exposure was one of the major problems preventing a commitment from Tower Hill. The Tower Hill facility has only one of the staple plants regularly in its inventory and has very limited space.

The issue of how to write the rules for the required greenhouse section was a continuing point of discussion in meetings between the team and Professor Wilkes. In meetings after Andrew’s portion of the project had begun and the work of the concurrently running design team was wrapping up, it became clear that the creation of a greenhouse section in the main Lunar Base Exhibit could not do justice to the importance and scale of the greenhouse in the Lunar Base infrastructure. Ultimately Andrew and Brian concluded that deciding whether or not the greenhouse should be a section in the Lunar Base was a question that could not reasonably be answered by the design contest entrants. In order to definitively answer the question of where the greenhouse section should be located, a botanical garden like the one at Tower Hill would need to commit to supporting the project and incorporate the staple plants present in a lunar base into their displays. We decided that while this would be the ideal option for the greenhouse it was also the most uncertain. Instead of leaving this question to the contestants to answer we decided that they should instead create the best activities and images they could for the greenhouse station without choosing a specific location for it. This would allow the greenhouse question to be answered later in the process of designing the exhibit, allowing the botanical garden to be shown as one option. Alternatively, imagery from a commercial greenhouse or an urban garden could be fed into either the control center, an in-exhibit greenhouse station, or both would also fulfill the same purpose. The rules were revised to reflect these possibilities, and it was required that every team must submit a plan to maintain the illusion of a massive lunar greenhouse as well as provide activities for a greenhouse station be it at Tower Hill or in the exhibit.

The use of the Tower Hill Botanical Garden remained the first choice for the greenhouse station and towards the end of the project Professor Wilkes went to negotiate with Tower Hill. These negotiations resulted in sufficient commitment from Tower Hill to allow us to revise the greenhouse rules to focus exclusively on their facilities. We could tell the participants that there would be a room set up with example of all the staples if Tower Hill did not have to pay for it, and a modest hydroponic display was also to be allowed. However, It was not to be permanent unless it could be integrated into the decorative collection and become part of a scavenger hunt. It could be set up for a few months, January to March. Then it would have to be taken off site for storage- presumably in another Greenhouse.

As the space provided was not well lit, the Tower Hill representative was concerned about the way that station of the exhibit would look if it was not integrated in to the main Tower Hill collection where there was good natural light. Ideally one could find a way to reflect natural light into that part of the Tower Hill facility, in keeping with the idea of an underground green house. However the fall back plan of a scavenger hunt for the staples and other useful plants was acceptable. At this point one could require the design of a portable station to physically be at Tower Hill, however these changes would need to be made after the submission of this report because of the short time between these negotiations and the submission deadline.

Finally, the last major modification to the original rules allowed for entrants to submit less than a complete entry to the contest. Originally teams were required to submit an Exhibit with six stations, of which one was required to be a greenhouse station. This later evolved into a complete entry consisting of six stations, one of which was required to be the command center, and an additional general station for the greenhouse. One of the ideas that were generated in discussions with Professor Wilkes was the idea that individuals who wanted to enter the contest but could not find a team might be allowed to submit smaller amount of stations. These stations would be evaluated separately from the main contest, with support to be drawn from a smaller prize pool, and would be presented to the architects along with the judge's evaluation of the entries for the educational design contest during the second phase. Allowing incomplete entries by individuals or teams smaller than the recommended size ensures that students with good ideas will not be prevented from entering the contest merely because of a lack of a team. Ideally, these smaller entries will allow an individual or undermanned team to still create high quality contributions to the contest without having to devote resources or time to finding and managing a team that may not have as passionate an interest in the contest, merely for the sake of gaining entry.

## Supplemental Documents for the Contest and Website

In addition to the explicit requirements outlined in the rules of the contest, many of the meetings with Professor Wilkes after Andrew had begun work revolved around the direction in which the educational teams were intended to take their work if it was to be of use. One of Andrew's major contributions was the creation of supplemental documents to give examples and guidance to teams with regards to what they were expected to include in their stations without explicitly requiring these examples in the rules. One of the main goals of the contest rules that we decided on early in our project was to avoid over-specifying any parts of the contest where possible. We decided that the more flexibility the teams could be given, the more they would be able to innovate and create a truly exceptional entry. Therefore many of the possible components of the exhibit that were discussed in meetings with Professor Wilkes were not suited for inclusion as a requirement in the contest rules. However these possible components were considered highly desirable and represented a design direction that would produce entries closely matching the original vision of the exhibit. Therefore in order to provide teams with a foundation on which to build and to guide them in the design process by way of example several documents were created that, although not official parts of the rules, were identified as supplemental material to help contest entrants get started. These documents, when completed, were intended to be displayed alongside the rules in the website. These usually consisted of a general suggestion document containing examples of some stations the teams might create as well as what could be taught at those stations, a points rubric to give the teams a general sense of how to prioritize their efforts, a list of infrastructure that would be found in the lunar base, and a list of revenue streams explaining the different ways the exhibit might be able to generate revenue beyond the primary goal of being a field-trip destination for students in grades 5-9. Other supporting material was also created for the website to fill various needs that were identified over discussions between Professor Wilkes and us.

One of these documents, referred to as the suggestions document and included in the Appendices, gave examples of what lunar base functions a team might choose to base a station on. Among these topics were those functions discussed in meetings with Professor Wilkes as appropriate for teaching certain topics. These suggested stations were also accompanied by suggestions for activities that could be conducted at the station, including an explanation of what the activity might teach. This document was created to give teams the same insight into Professor Wilkes' vision for the Lunar Base Exhibit as we have received through our meetings and conversations with him. The programs written last year to shape an architectural contest were no longer useful for the design contest at the outset of our project, however because of the changes to more closely reflect the original intent these programs again became relevant to these guidance documents. This vision, drawn from Professor Wilkes and prior program teams, provides teams with a foundation to build from, however it is not a strict requirement of the rules and teams are in fact encouraged to generate their own ideas in addition to or instead of the suggested stations in this document.

Another important supplemental document that was created was a Points Rubric that demonstrates roughly how much each part of the design will be weighted by the contest judges. One of the problems that came up frequently in conversations with Professor Wilkes was the desire for stations and the exhibit as a whole to have certain features that would improve the quality of the educational activities, protect potential revenue streams, or make constructing the final exhibit easier. Specifically one of the key points included the desire to have a flexible difficulty level of the activities at each station; allowing teachers to request difficulty levels that better suit their classes' needs. In addition to the modification of the difficulty of an activity the activities could ideally serve as either an introduction or a review to the relevant topic depending on when in the school year the students visit the exhibit. It is not clear whether exhibit should have levels or whether the whole exhibit should be reconfigured for each grade level with different stations and a different mix of concepts. It is not hard to envision keeping a set up for 5$^{th}$ graders lasting a month and then a month long set up for 7$^{th}$ graders followed by a month set up for 8$^{th}$ graders and another month for 5$^{th}$ graders. A given teacher could decide that their 4$^{th}$ graders can do the 5$^{th}$ grade material or that a science orient school might put the 5$^{th}$ graders in the 7$^{th}$ grade program,. The general idea is to make it attractive for the students to come with their class every year, grades 5-8 and have a totally different experience each year. This has obvious revenue stream implications as well as educational continuity in the integrative themes.

Another specific desire that is strongly related to the existence of the second architectural design contest is that any stations created by the teams are modular, meaning any station could be removed or added to any other exhibit without relying on material in other stations. This second function in particular would be excessively specific to impose on a team, given that in an actual Lunar Base everything is interconnected and that there is a large potential for creative and exciting uses of interconnected stations. Neither of these desires was sufficiently crucial to warrant inclusion in the explicit rules requirements; however we decided that by adding these goals to the points rubric as somewhat minor additional sources of points, teams that were looking to design their stations to be largely independent would put the extra effort in to ensure modularity, for example. However the amount of points offered by these requirements was selected to be sufficiently low that a team that had an excellent vision for a fully interconnected exhibit could pursue that vision without sacrificing too many points. The rubric was also structured in such a way that teams losing points in one area, such as by having an interconnected exhibit, could reasonably expect to gain them back in other categories such as the use of the lunar theme in their stations. This rubric will give teams a fair understanding of exactly how the contest will be evaluated, as well as guide teams without a strong vision down a design path that we are certain is useful.

One of the problems encountered when handling and later evaluating the work done by the concurrent design team was the difficulty they had envisioning the various infrastructure components that would either be part of a base or co-exist with a Lunar Base, though they might be in orbit –even another planet’s orbit. Even excluding the pieces of the infrastructure in the base proper, there is a lot of other infrastructure that would be present given the existence of such a Lunar Base giving it both a purpose and a historical context. The Lunar Base Infrastructure document was created to address these observations by providing teams with a list of the component pieces of infrastructure one could expect to find in a Lunar Base. This document can be found in the appendices and explains pieces of infrastructure outside the base itself such as the ice water harvesting operation and the glassed roads used to traverse the lunar surface and sometimes a crater outside the base.

The final document directly supporting contestants was the document explaining the alternative revenue streams expected for the Lunar Base Exhibit. These revenue streams are a key part of the financial feasibility of the exhibit and more importantly the renovations that would be done to the Worcester Auditorium. The desire to protect these revenue streams is included in the points rubric as a means of guiding the teams to take the extra time to ensure these options remain open. These range from being an attractive destination for families on the weekend to being usable as the set for a TV show. The document itself contains explanations of the several alternative revenue streams envisioned as well as what teams would need to do in order to ensure they remain possible.

The changes to the rules of the design contest done throughout this project, as well as the supporting material created for the contest, have resulted in a contest that is well and truly ready to be run. Several of the major decisions made during our project have directly translated into significant alterations to the rules of the design contest. Without these changes had the design contest run on schedule it certainly would have produced results far afield from the original intentions of Professor Wilkes and the AIAA. With these new rules and supporting documents, as well as the publicity material created both by Brian and Sarah during their work, and by Andrew during his, the contest is now ready to be brought to a wider audience and hopefully brighten the future of science education in Worcester.

# **Marketing the Lunar Base Exhibit Contest**

## AIAA YPSE Laurel, Maryland

In mid-November it was decided that one of us should go to the Young Professional, Student, and Education (YPSE) Conference in Laurel, Maryland and give a presentation, on the existence and some background information of the contest to the undergraduate and graduate in the field of aerospace in the many schools in AIAA Region 1. It did not get into many details of the contest, however it supplied some parameters on what we expect a team to consist of and information on the Worcester Auditorium. The main purpose of this trip was to get the idea out there among the aerospace students that there was a contest for designing a lunar base exhibit being made and that we are looking for teams to enter for a most likely September 2014 launch, which coincides with the first semester of that academic year.

The decision to go to the YPSE conference was made one week before the actual conference. This made the presentation rushed to completion, and the member, Brian Scholwin, had little time to prepare for his presentation, and worked up until the time the presentation had to be given to produce it. This meant that there was very little time to practice this presentation. His power point are includes in Appendix A.

After all the work that went into this presentation the actual delivery went as well as could be expected, with the amount of practice that was done. However, there was one major problem when the presentation was given, and that was our target audience did not come to see any of the presentations during that block, and only an older crowd was there. While this was great for the education orientated presentations, our presentation did not reach out to the audience we had in mind, which limited our ability to market the contest at that time.

The YPSE conference taught us many things even though our target audience was not present at the time of our presentation. From the people that did attend our presentation their major concern with it was the amount of capital it would require to renovate the Worcester Auditorium. The amount that is needed to renovate the first floor of the Worcester Auditorium is fifty million US dollars, and to renovate the basement, where we would like to place this exhibit would be another ten million US dollars.

Without a business plan we couldn’t be taken seriously, which led use to 1 decision, to either come up with a scenario to that could justify a whole Air and Space Museum in the Worcester Auditorium or just a business plan that would work for renovating the basement for the lunar base exhibit. The key to this plan would be to keep the lunar base exhibit relatively cheap for the Worcester public Schools, so they would be more incline to come back to this exhibit year after year for five years. With this project we were giving coming to an end this is one of the tasks that would be giving to the next project team. However we did come up with a scenario that could work as background for the contest, as a type of problem statement. Though this is not worked out in detail and still needs to be worded elegantly, it can still be used as a problem statement which can help solve the problem of the YPSE presentation not taken seriously.

This scenario describes a way this type of project could be funded, by a partnership between the city and colleges of Worcester. In short;

"The colleges of Worcester agreed with the City of Worcester to a payment in lieu of taxes (pilot) rendered to the City of Worcester of $100 per student per year. Currently in Worcester there are about 30,000 students among 10 colleges. In total the amount the colleges pay would be about $3 million per year, and this would be used to help renovate the Worcester Auditorium. This would raise about half the capital required for the entire Air and Space Museum, which includes a lunar base exhibit in 10 years, and in anticipation of the income steam the city could borrow against it. At this point the city would qualify for matching funds and grants from the State and federal governments of the type used to build schools.

The resulting facility would be worth more than $50 Million and in return for this investment; the building will now be owned by the Worcester Public Schools and co-owned by the Colleges of Worcester, each with 50% ownership of the property. The primary use for this would be for the Public Schools, with students volunteering for credit for a space minor.

Your job is to design an exhibit that represents a lunar base environment that will take up approximately half of the 40,000 square feet floor space of the basement of the Worcester Auditorium. The other half will be used for a Mars base exhibit. About $10 Million is available for the project as a whole, but 60% will be used for basic cleaning and renovations including structural repair and restroom facilities. The exhibits are to cost about $4 Million in all. The State and federal funds will cover the basic renovation to a sound building with modern facilities. The pilot revenue would be used to decorate this space to fit the theme and construct the actual science education exhibits. You as a technical design team are to assume you have a $1 million budget on the actual activity station exhibits, and the rest will go to the Architects who will come on later to make the facility look and feel as a structure that is placed far away and in the future.

If your team goes over budget, or think you went over budget you must justify why funds must be reallocated to your design, as this would take away from the budget of the architects. Hence you must state why this educational exhibit is superior as to justify a larger budget."

With something that is equivalent to this problem statement for the actual contest we hope to gain some credibility. This will also help the participant engage this task as they will have a better understanding of the reasons behind some of the contest parameters and give the contestant the belief that something like this can really happen if they do an impressive job on their design. For the moment we will ignore the first floor flexible space that is set up as a Goddard exhibit half of the time, as for the scope of this contest the Goddard exhibit is of lesser importance. The Lunar Base exhibit in the basement is permanent and dedicated to science education, and such is the case for the Mars Base exhibit. The difference between the two will be instructive.

## Additional attempts to Market Lunar Base Exhibit Design Contest

After the YPSE conference in Maryland we saw that there was a need to do additional marketing for this contest. To do this we put together a list of the AIAA sections in Region 1 with their corresponding presidents and communication officers if they had any. The full list can be found in Appendix D. With this list we would send out the Cover Letter that is part of Appendix D, and the handout that was used during the YPSE conference. One problem with this was that one objective of this document was to direct those interested to a Web Page with details, however that web page was not yet ready for use.

The end result we are hoping for is to send these documents to various colleges or universities with an AIAA chapter in them, through the professional AIAA chapter. With that we could then set up meetings with the colleges or universities where Professor John Wilkes could give a presentation on, similar to the one used in the YPSE conference found in Appendix A. This would hopefully do what the presentation at YPSE conference failed to do, get the idea that this contest exists and start to stimulate interest in this subject matter between the aerospace, civil and robotics students in those colleges or universities. This would also help recruit faculty at these colleges or universities to advice a project similar to our contest, or offer courses, or independent study where the final project would be to design something like this so students could get academic credit for their work as well. However to do this we wanted Professor Wilkes to go out to these colleges and universities who showed interest in hearing about this contest during January and February of 2014 and give this presentation. This would allow talk about this contest to being to spread which would give us one of the best marketing tactics, “word of mouth” which we fail to achieve at the YPSE conference back in min-November.

This however never happened, as the documents required never got sent to the colleges or universities with an AIAA chapter, because the web site for the additional information was never set up in time for this to happen. However when the web site is finished future teams will be able to use what we have compiled in both Appendix A and D, the YPSE presentation, draft letters, and AIAA contact list to make these meeting an actual reality in the future, which would be a great source of marketing for the contest, when the web site is completed.

## Appendix A: YPSE Presentation and Handout

# Plans For Educational Exhibits Simulating Moon and Mars Bases

By Brian Scholwin
Physics Major at WPI

## Envisioning an Air and Space Museum-with a difference

- It would be dedicated to the Memory and Vision of Robert Goddard- WPI Grad. 1908
- Located in the abandoned Worcester auditorium
  - built in 1930's – honors WWI dead
- But is inspired by a 2010 Architectural contest designing Lunar Bases circa 2069.
- It would look forward 56 years as well as back to the Goddard (and Apollo) Eras.

Top: Robert Goddard

Bottom: Main Street Entrance to the Worcester Auditorium

# Images of the Worcester Auditorium

Top: Mural in the Worcester Auditorium

Bottom: Deteriation of the outside of the Worcester Auditorium

## Images of the Worcester Auditorium

Top: Basement in 2010

Bottom: Main Floor, from balcony 2012

## Sponsorship and mission of the Lunar exhibit

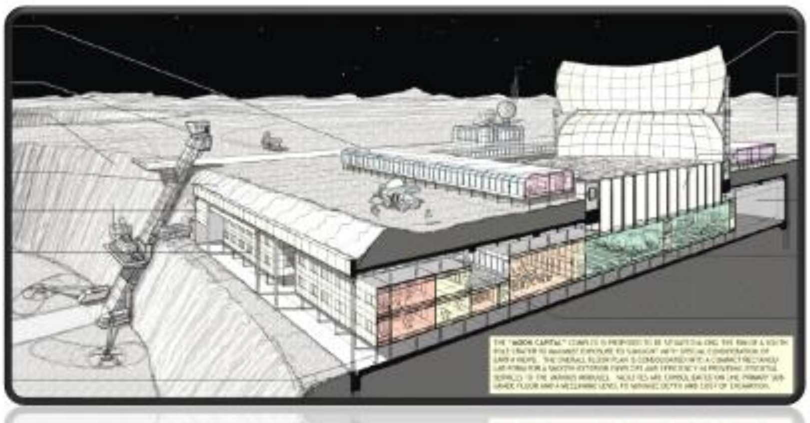
- 2010 lunar base architectural contest was co - sponsored by Shiftboston and AIAA New England chapter
  - In 2012 WPI students proposed a second architectural contest in 2014 focusing on an educational exhibit depicting an interior of a Lunar Base
- These students did a technical feasibility review of the 102 entries in the 2010 contest, 22 were feasible, with 2 being the best
  - These technically feasible and elegant entries inspired the idea of a second contest
  - Both sponsors of the 2010 contest have approved the idea of a second contest to produce images that might lead to actual construction
  - The Ecotarium of Worcester also wish to find designs for a 250 sq. ft. exhibit

## Co-Winner Feasible Design from 2010 Contest(Benoit, Wilkes et.al.)

## Craterville Interior Views

Drawings from Professor Barbara Kimball of Interior Design at Becker College

# Co-Winner Feasible Design from 2010 Contest(Tom Schmit)



## Tom Schmit's Moon Base Interior

Top:Single Room

Bottom: Cut away

Use light flexible imported portable panels

# Outside View of Tom Schmit's Moon Base

# Educational Mission

- Designed to reflect the base interior and be the location for "ultimate science field trip"
  - Primary audience 5th to 8th graders.
- Space Themed Science Curriculum already under construction
  - 5th grade covers solar system, matter, energy, electricity, light, forces and motion
  - 6th grade adds biology- especially botany- to mix.
  - 7th grade robotics, technical design and chemistry
  - 8th grade biology, physics and robotics

# Fleshing out the Exhibit Elements

- First Floor and Balcony- Goddard Exhibit
  - estimated renovation and exhibit- $50,000,000
- Basement split between Lunar and Mars Bases
  - Second Generation Lunar Base
    - (made of local materials and feeds, pays for self)
  - First Generation Mars Base -Minimum settlement
    - ( One Way Missions Stress Robotics and 3 D Printers)
  - Estimated renovation and exhibits $10,000,000

# Focus of my Talk

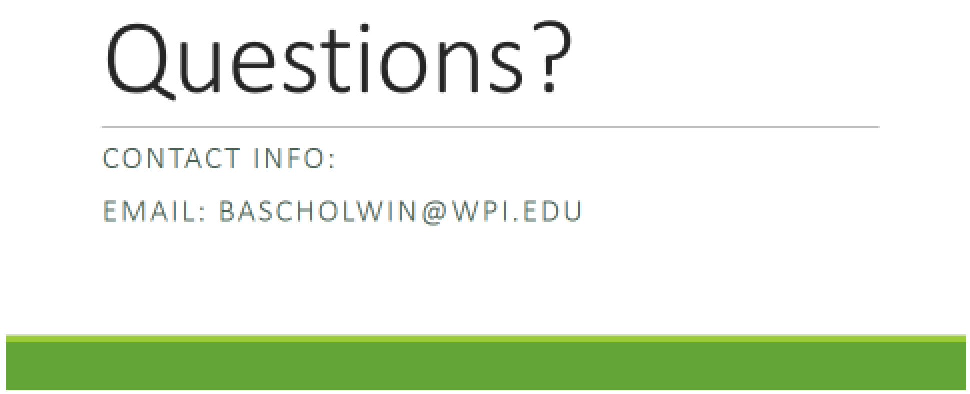
- Contest mission
  - To produce images around which to focus a local debate on the case for such an exhibit
- The contest specifics
  - Architectural Program
  - Where the exhibit will probably be
  - Requirements for the Exhibit
  - Requirements for contest submissions

# Classes of Entry

- Team Entries, what we recommend
  - Interdisciplinary teams
  - Focus on entire exhibit
- Individual Entries
  - Focus on one or two secsions of the exhibit
  - Judged separately from Team Entries

# We Invite You Enter

- Team entries
  - Possibility for your design to be used in a $10M to $50M project
  - Experience working in interdisciplinary teams
- Individual entries
  - Possibility for your design to be used by the Ecotarium of Worcester
    - Exhibits are usually given $4M in funding
- We Challenge you to enter and make the "Ultimate Field Trip"




Handout Front Page

**Invitation to a Grand Adventure: An Educational Exhibit Design Competition.**

The idea of settling on a Lunar Base within the next 60 years may seem impossible, but there are designs already in place to occupy the Moon by 2069, 100 years after we first set foot on the Moon. Design ideas in themselves are always a bit abstract and can be difficult to visualize. But, what if you could step inside a full-sized model of a proposed base? What if you could interact with and seem to operate different components of a lunar base? We invite current college student teams and individuals majoring in architecture, engineering and other fields to enter a design competition to create such an educational space. You will be depicting a future and faraway place in the basement of a large building for a specific 10-15 year old audience. We offer the specification of a real building in Worcester for your use, if you do not have another specific existing building in mind suitable for this purpose in your own city.

The premise of the Lunar Base Exhibit Competition to design a place for teachers to takes their classes on the ultimate science education field trip. Utilizing the large and currently unoccupied space in the cavernous basement of the Worcester Memorial Auditorium, your goal is to transform half of this space into a Lunar Base Exhibit for students grades 5-8 can go to experience another world. (The other half of this space will later become a contrasting Mars base.)

If constructed, this exhibit would become the ultimate field trip capstone to a unique curriculum being developed now in 5th-8th grade classes. It would be an extraordinary opportunity for students in the Worcester region to apply what they have learned in science class to the problem of living and working in space. Thus it is an invitation to be part of a great historical moment their generation will experience at the opening of a new Age of Discovery. We hope that they will become excited about space travel and support construction of a settlement on the Moon that can feed and pay for itself. The rest of the exhibit will take them farther into this vision of the future. However, whether they do or not they will learn some science and connect the concepts they have learned to a vivid and memorable experience.

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Contact John Wilkes, Brian Scholwin or Sara Triplet of WPI for details

jmwilkes@wpi.edu
bascholwin@wpi.edu
striiett@wpi.edu

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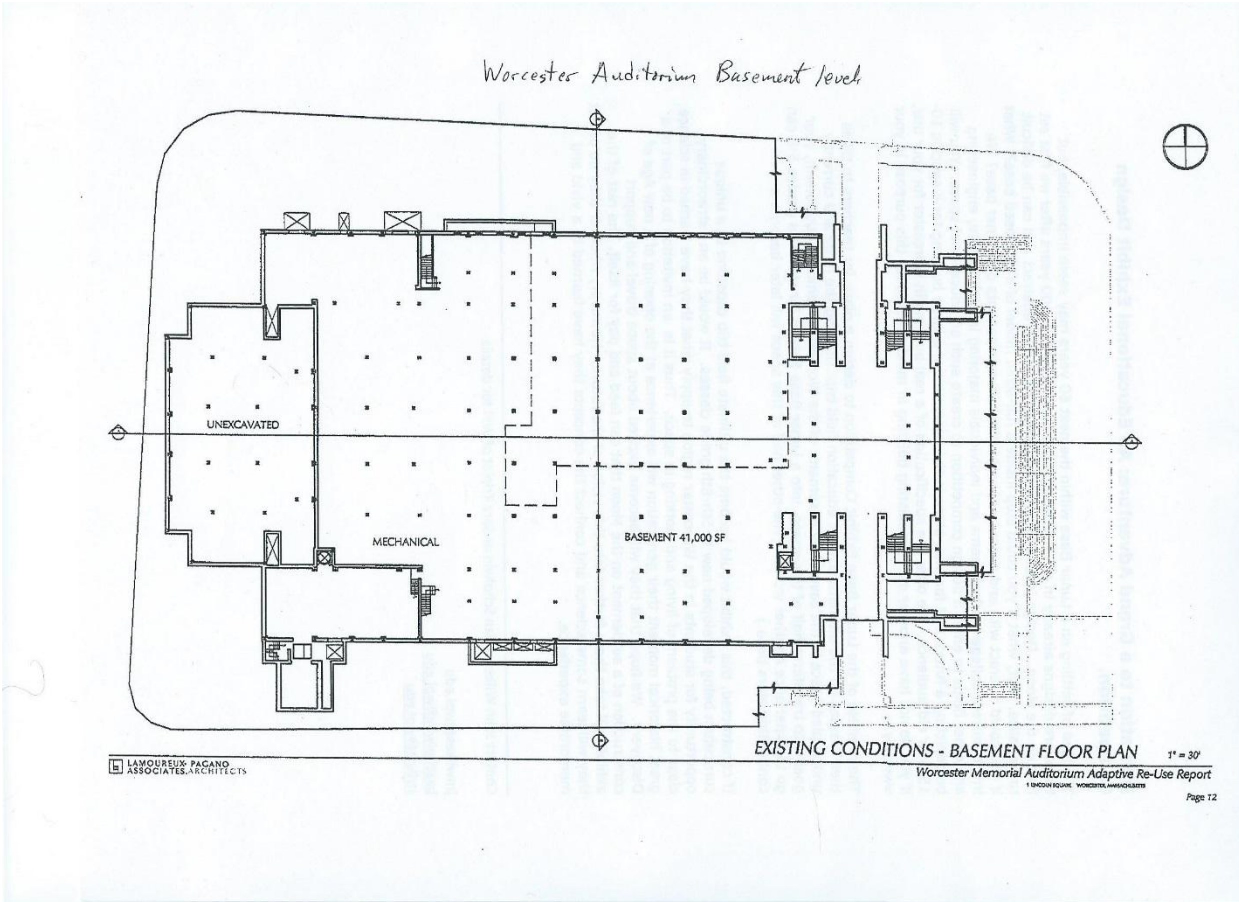
Worcester Auditorium Basement level
UNEXCAVATED
MECHANICAL
BASEMENT 41,000 SF
EXISTING CONDITIONS - BASEMENT FLOOR PLAN
1" = 30'
LAMOUREUX PAGANO ASSOCIATES ARCHITECTS
Worcester Memorial Auditorium Adaptive Re-Use Report
1 LINCOLN SQUARE WORCESTER, MASSACHUSETTS
Page 12

## Appendix B: Rules and regulations as of 12/14/2013

**WHO:** Interdisciplinary Teams of University Students (Graduate and Undergraduate Divisions) with a faculty coach or coaches from any discipline. Students can use this as a project for a class, independent study, or for club activities, it isn't however necessary for an entire class to participate. Team members do not have to be from the same campus. Three technical majors (for example aerospace, civil engineering, biology etc.), can team up with an education, artistic design, or architectural student. These are among the suggested disciplines for team, however anyone can enter as an individual or a team. If you have difficulty finding an architectural student, or your university doesn't offer an architecture major, Shiftboston will assist you in finding architectural students to team up with.

**MISSION:** Design a large scale space-enriched education exhibit that looks like part of the interior of a lunar base. It should mimic a base designed to house about 60 people (and a few semiautonomous robots that work indoors; there will be the illusion of at least 300 more outside) at either the north or, south pole of the Moon. Shackleton Crater in the south pole of the moon is an already approved site for this base; NASA is considering it and we believe a large amount of ice can be found there. It is a suitable location for a lunar base for other reasons as well, the primary one being near continuous sunlight, however if there is another lunar location which you would like to use for imagery and inspiration, it would have to be approved first.
This exhibit is to be circa 2069, the 100th anniversary of the first Apollo lunar landing. Returning to the exhibit specification, it should be a hands-on children's museum for students in grade 5 to 9, with about 100 students arriving at a time. They will visit annually. Curriculum units it must support are as follows:

- 5th grade: physical science (solar system, matter, forces, energy, light and sound, electricity, including solar-generated electricity and photovoltaics)
- 6th grade: plant biology & the biosphere, as well as a review of the solar system and forces - students will go offsite to Tower Hill for the plant biology unit
- 7th grade: chemistry and robotics
- 8th grade: biology and robotics (botany, greenhouse, and the impact of space on the human body)
- 9th grade: physics and astronomy

All units are designed to be a preparation and review for the MCAS, a state achievement test taken in 10th grade that is a High School graduation requirement, in Massachusetts. If you wish to use a building in another state and it is approved, you will have to fit your exhibit to the statewide achievement test in that particular state.
The exhibit must be able to handle an average of three classes of 30 students each and a maximum of 120 studets (and one teacher or chaperone for each 10 children) including feeding them lunch and handling trips to the bathroom.

**WHEN: Jan 2014-April 2014; a technical feasibility and scientific accuracy review submission is due from each entry by the beginning of April.** Shiftboston will make available to all contestants the finalist designs for a circa 2069 Lunar base for 60 people, produced during its 2010 Moon Base contest. The two standout "feasible" base designs that shared the "technical feasibility and technical elegance" prize will be offered as examples of the kind of base one is trying to depict and simulate, but on request, 3-5 “honorable mentions” with fixable flaws will be provided as well.

**WHAT:** A valid submission will involve 1-2 electronically submitted boards and up to ten pages of supporting text. There is a technical feasibility and scientific accuracy review due from each entry by April 1st, 2014.
Technical requirements:

- Design must:
    - work in a lunar environment
    - be constructed 90% of materials found on the moon, and
    - get the physical science concepts to be taught right
- At a minimum, it will include:
    - a mission control center
    - a robot fleet maintenance and reconfiguration area
    - a materials extraction unit that processes lunar regolith
    - human habitat living area

It will incorporate an exhibit with imagery from a rearranged greenhouse based on one of the existing greenhouses at Tower Hill Botanical Garden, in Boylston MA, depicting it as if it were one floor above the human habitat in the lunar base, although Tower Hill is 10 miles away. This site specification is only applicable if your exhibit is based on the Worcester, MA building information that will be provided, if you wish to use another site, see the next section, and you’ll have to find asuitable greenhouse to get approved as well. The third option to this if there isn’t a Botanical garden, or another greenhouse site, near the site that you got accept and approved, is assuming that telecommunication with Tower Hill is possible and find a way to incorporate this aspect into your exhibit, however this would also assume that a field trip to Tower Hill isn’t possible for your target audience.

**WHERE:** It must be designed to fit in an existing building that is vacant, underutilized, or can be made available to a school system. Ideally it will be presented as an urban architecture preservation project in service to the public schools and supported by local colleges and volunteers. Since a lunar base would be underground, the basement of a public building would be ideal. For instance, for Worcester project teams, the currently empty Worcester Auditorium is a suitable place. Its cavernous basement specifications are offered to all contestants as a space that has been pre-approved for this use. Another space of the same size in another city can be used, but it must be approved by the organizing committee. This will involve a plan for depicting it as an underground space if it is in fact a 19th century public school building on 3 floors or an abandoned factory.

**COST:** There is a $100.00 entry and processing fee that must be paid by the end of January 2014. Late entries will be accepted up until February 10th, 2014, but the registration fee will be $150.00 after January 31st. (AIAA scholarships are available to those who find a hardship or serious burden to enter)

**TEAM SUPPORT:** A contestant (team) can have up to three supporting organizations in addition to their college or university so long as they are noted as sponsors on the entry. These can be a museum, a corporation, an architectural firm, a public school, a professional organization, or a city urban redevelopment agency, so long as they remain in a consulting role.

# Appendix C: Material for Marketing Contest

Cover Letter:

Dear Students at college, or university

We, the students at Worcester Polytechnic Institute (WPI) are trying to put together a contest where a team or individual can design a lunar base exhibit for a space enriched education.

For the people who are interested we will give you specifications for an approved location the Worcester Auditorium in Worcester, Massachusetts, which has a basement with 40,000 square feet of space and has a cavernous feel which would be ideal for a lunar base exhibit and gives you plenty of room to design the best lunar base exhibit you can.

This exhibit that you are going to design is to be educationally rich for fourth to eighth graders, as well as being technically feasible in a space environment. There will be a technical review before the contest ends.

For the best designs there will be a first, second, and third place, along with honorable mentions. These winners may also join the AiAA in November for their annual meeting and give a presentation on their design.

Sincerely,

Lunar Base Contest Management Team 2013:

Brian Scholwin

Sarah Triplett

Professor John Wilkes

List of AiAA Chapter's presidents and/or communication officer:

AiAA Section chairmen and communication officers

**Central Pennsylvania Section**
Chairman: Mark D. MAughmer
Communications:

**Connecticut Section**

**Delaware Section**
Chairperson: Eric Spero

Communications:

**Greater Philadelphia Section**
Vice-Chair: Joseph Wagner
Communications:

**Hampton Roads Section**
Chair: Eric L. Walker
Communications:

**Long Island Section**
Chairman: David Paris
Communications:

**Mid-Atlantic Section**
Chain Robin Vaughan
Communications:

**National Capital Section**
**Chair: Dr. Supriya Banerjee**
**Communications:**

**New England Section**
Chair: Anthony Linn
Communications: Anthony Linn

**Niagara Frontier Section**
Chair: Walter Gordon
Communications:

**Northeastern New York Section**
Chair: Eric Ruggiero
Communications:

**Northern New Jersey Section**
Chairperson: Raymond Trohanowsky
Communications:

**Southern New Jersey Section**
Chair: Michael Konyak
Communications:

## Appendix D: Draft Greenhouse Rules

The Greenhouse exhibit that is the main site of biological science education and the only place that botany is addressed. Hence it is something that requires special thought and is more rule bound than the other parts of the exhibit. A case could be made for not having a greenhouse station inside the exhibit. One could tie into an existing botanical garden and view it through mission control with the understanding that it is to be visited at another time, or one could have just a video feed from a sizeable commercial greenhouse fed into mission control with no hope of an actual field trip to that site. If a part of the exhibit area is to be devoted to a greenhouse thought about how to make it look large enough to be 40% of the base is needed.

One possibility is to leave the actual biology to others and focus on the factors that go into locating and building such an agricultural facility. Concurrently one can set up an experiment dealing with the consequences of different decisions along these lines and exhibit only the experiments rather than the resulting facility. For example, we are modeling a lunar base located at the south pole of the moon. Why is it there? What would it mean if it was placed near the equator of the Moon?

The design challenge that you face at the equator is how to supply enough light for the plants to thrive in a pattern of fourteen Earth days of sunlight, and fourteen Earth days of no sunlight. At the poles there is light all the time, but it keeps changing the direction from which it shines. If one does not build on the surface, or bring in light from the surface, but rather builds the base into the side of a crater, again there will be 14 days each of light and dark, unless one places a reflecting device on the opposite side of the creator. Given the time available to the visiting students should probably offer the students an array of options from which to choose as a design review and choice challenge activity.

It would help if they could see the effects of the different light patterns on actual plants in deciding whether or not they had to compensate for the dark periods or create periods of darkness, for at least some of the plants.

In summary, the Greenhouse exhibit should ( at a minimum) provide the opportunity to learn about a balanced plant-animal biosphere, address the question of what plants should be grown to supply the needs of the base and address the question of lighting tied to location of the base.

In the latter question, if one decides not to include a greenhouse exhibit in the main facility should still demonstrate at least 3 types of scenarios to set up a later field trip to another site. These are:

- 14 Days of sunlight and 14 Days of No sunlight

- 24/7 of light, possibly but not necessarily rotating around the plant from a different position every day for 28 days.
- An Earth-like scenario, where plants get about 12-14 hours of sunlight and 10-12 hours of no sunlight to use as a control group.

As noted, if one declines to put in a greenhouse exhibit, one needs to come up with another way to address at least the location question as part of another exhibit. This could be addressed by a cyber space greenhouse exhibit presented as being at another location that is accessible through mission control. One can put off the botany and nutrition issue until the 6th grade program but biosphere balance and location questions need to be addressed in some way as part of the main lunar base exhibit designed to be visited by 5th graders.

The nearest first class Botanical Garden, and one that is close enough to support a local student field trip from Worcester, is the Botanical Garden at Tower Hill, in West Boylston. Unfortunately it emphasizes ornamental rather than food stock plants. However it must be decided whether students will go to this site or if imagery will be imported to your exhibit using some method. Another option is to make a greenhouse exhibit in your design, but supplement it in some way to give the illusion of a large facility on "another floor" of the main facility they are visiting. One can explain why they can't visit it by claiming that the atmosphere is toxic to humans but advantageous to plants, as long as one finds a way to explain the difference and offers a rationale for it.

At some point in your proposed program, at the Auditorium or elsewhere, one should address the question of which plants they propose to take to the lunar greenhouse and why. These plants must include a choice between staples and also satisfy a balanced diet for the people who inhabit the Lunar Base.

Some of the existing 6th grade curriculum goes into this question and also proposes that there be two greenhouses, only one of which would have an atmosphere toxic to humans. Both would have to be involved in the description of the gas exchange between various rooms housing plants and mostly human animals.

The usual explanation for two greenhouses is that there are two kinds of photosynthesis, C3 and C4. It is the C3 plants that benefit from a higher CO2 level in the atmosphere. Since it is C3 plants that thrive in a high $CO_2$ environment and C4 plants thrive in a lower $CO_2$ comfortable for humans there is the question of where to put the two kinds of plants. Ideally you would want to keep your C3 plants separate from the rest of your base and either increase the carbon dioxide levels or somehow extract some of the oxygen the plants produce from this greenhouse.

This biosphere and location questions are the only mandatory educational tie in that is specified by the contest managers that limits the kind of science to be taught at the main exhibit.

However, it is strongly recommended that photosynthesis is mentioned, where the light will come from is addressed and why there are two areas of the base in which plants are grown.

**Appendix E: Final Rules & Documents**

# Lunar Base Exhibit Technical Design Contest

**WHO:** Teams of University Students (Graduate and Undergraduate Divisions) with a faculty coach or coaches from any discipline. Students are not barred from using their entry to this contest for any university class or contest insofar as the rules of this contest are concerned. Team members do not have to be from the same campus. Any combination of majors is permitted, however it is strongly suggested that teams incorporate members with knowledge of the required areas of biology, physics, chemistry, and engineering. Submissions for less than the full exhibit are permitted, and the requirements for these submissions are included below. The minimum and maximum team sizes for submissions are as follows:

Single exhibit: 1 person
Two exhibits: 1-2 people
Three exhibits: 2-3 people
Full entry: 3-6 people

**MISSION:** Design a large scale space-enriched education exhibit that looks like part of the interior of a lunar base. It should mimic a base designed to house about 60 people (and a few semiautonomous robots that work indoors; there will be the illusion of at least 300 more outside) at either the north or, south pole of the Moon. Shackleton Crater in the south pole of the moon is an already approved site for this base; NASA is considering it and we believe a large amount of ice can be found there. It is a suitable location for a lunar base for other reasons as well, the primary one being near continuous sunlight, however if there is another lunar location which you would like to use for imagery and inspiration, it would have to be approved first. This exhibit is to be circa 2069, the 100th anniversary of the first Apollo lunar landing.  Returning to the exhibit specification, it should be a hands-on children's museum for students in grade 5 to 9, with about 100 students arriving at a time.  They will visit annually. Curriculum units it must support are as follows:

- 5th grade: physical science (solar system, matter, forces, energy, light and sound, electricity, including solar-generated electricity and photovoltaics)
- 6th grade: plant biology & the biosphere, as well as a review of the solar system and forces - students will go offsite to Tower Hill for the plant biology unit
- 7th grade: chemistry and robotics
- 8th grade: biology and robotics (botany, greenhouse, and the impact of space on the human body)
- 9th grade: physics and astronomy

All units are designed to be a preparation and review for the MCAS, a state achievement test taken in 10th grade that is a High School graduation requirement, in Massachusetts. If you wish to use a building in another state and it is approved, you will have to fit your exhibit to the statewide achievement test in that particular state. The exhibit must be able to handle an average of three classes of 30 students each and a maximum of 120 studets (and one teacher or chaperone for each 10 children) including feeding them lunch and handling trips to the bathroom.

**WHAT:** A valid submission for a full team will involve 1-2 electronically submitted boards and up to ten pages of supporting text. It will incorporate an exhibit with imagery from a rearranged greenhouse based on either Tower Hill Botanical Garden, in Boylston MA, or a commercial greenhouse.

Technical requirements:

- Design must:
  - Include 6 separate stations
  - Include educational activities for each station
  - Of the six stations, one must be the command center
    - See the command center rules for more details
  - The greenhouse activities must be submitted in addition to the 6 exhibits
    - See the greenhouse rules for more details
  - Educational activities must be based on the curriculum taught to each grade

Valid submissions for single or two exhibit entries may incorporate the greenhouse if they wish but will not count towards their exhibit total. There are no required exhibits for teams submitting less than a full entry.

**WHERE:** It must be designed to fit in an existing building that is vacant, underutilized, or can be made available to a school system. Ideally it will be presented as an urban architecture preservation project in service to the public schools and supported by local colleges and volunteers. Since a lunar base would be underground, the basement of a public building would be ideal. The empty Worcester Auditorium basement is the intended location for this contest, however if a team wishes to use another building is a suitable place they may contact the judges and request an exemption. Its cavernous basement specifications are offered to all contestants as a space that has been pre-approved for this use. This will involve a plan for depicting it as an underground space if it is in fact a 19th century public school building on 3 floors or an abandoned factory.

**COST:** There is a $100.00 entry and processing fee that must be paid no more than ten days after the submission deadline.

**TEAM SUPPORT:** A contestant (team) can have up to three supporting organizations in addition to their college or university so long as they are noted as sponsors on the entry. These can be a museum, a corporation, an architectural firm, a public school, a professional organization, or a city urban redevelopment agency, so long as they remain in a consulting role.

# Lunar Base Exhibit Architectural Design Contest

**MISSION:** Expand and improve on existing technical designs for a lunar base themed science exhibit targeted at 5th-8th grader students. The lunar base on which the exhibit is based houses approximately 60 people, as well as several hundred semi-autonomous and completely autonomous robots, most of which perform activities outside the habitable base environment. The lunar base is located in a crater at one of the lunar poles, specifically modeled on Shackleton Crater in the lunar South Pole. Shackleton Crater is an already approved site for this base; NASA is considering it and we believe a large amount of ice can be found there. It is a suitable location for a lunar base for other reasons as well, the primary one being near continuous sunlight, however if there is another lunar location which you would like to use for imagery and inspiration, entrants may contact the tournament official(s) for approval and additional instruction. This exhibit is to be circa 2069, the 100th anniversary of the first Apollo lunar landing. Returning to the exhibit specification, it should be a hands-on children's museum for students in grade 5 to 9, with about 100 students arriving at a time. The technical design contest entries will support the following curriculum units for each grade:

- 5th grade: physical science (solar system, matter, forces, energy, light and sound, electricity, including solar-generated electricity and photovoltaic cells)
- 6th grade: plant biology & the biosphere, as well as a review of the solar system and forces - students will go offsite to Tower Hill for the plant biology unit
- 7th grade: chemistry and robotics
- 8th grade: biology and robotics (botany, greenhouse, and the impact of space on the human body)
- 9th grade: physics and astronomy

All units are designed to be a preparation and review for the MCAS, a state achievement test taken in 10th grade that is a High School graduation requirement, in Massachusetts. The building used by the winner of the technical design team will be the building worked with in this contest. The exhibit must be able to handle an average of three classes of 30 students each and a maximum of 120 students (and one teacher or chaperone for each 10 children) including feeding them lunch and handling trips to the bathroom. The goal of this design contest is to maintain as much of the technical design as possible while also providing visitors with the sensation that they are actually in a lunar base in 2069.

**WHO:** Architectural students or professionals interested in designing a major educational exhibit are encouraged to create and submit designs for the contest.

**WHAT:** A valid submission will involve one electronically submitted display board no larger than 5' by 5', and up to 5 pages of supporting text. Judges are not required to read any supplemental material and the entries will be judged in part based on the imagery on the display board, which will contain the floor plan for the design as well as a rendering of the command center. Anything else to be included on the display board is at the discretion of the submitting person(s).

Design Requirements:

- Provide adequate space for the movement of up to 140 adults and children simultaneously (approximately 120 children and 20 adults maximum)
- Provide ample space in each exhibit for up to 30 children and several adults
- Exhibits must appear to be located in a lunar base, as well as
- Space for activities at each exhibit as specified by the educational design must be included
- Provide space for storing equipment for each exhibit when it is not in use that is separate from the exhibits themselves
- Additionally, designs must be provided for a living area for the lunar base personnel

**WHERE:** It must be designed to fit in an existing building that is vacant, underutilized, or can be made available to a school system. Ideally it will be presented as an urban architecture preservation project in service to the public schools and supported by local colleges and volunteers. Since a lunar base would be underground, the basement of a public building would be ideal. For instance, for Worcester project teams, the currently empty Worcester Auditorium is a suitable place. Its cavernous basement specifications are offered to all contestants as a space that has been pre-approved for this use. Another space of the same size in another city can be used, but it must be approved by the organizing committee. This will involve a plan for depicting it as an underground space if it is in fact a 19th century public school building on 3 floors or an abandoned factory. It is strongly suggested that the building chosen be the building used by the educational design team, but other options are possible

**COST:** There is a $100.00 entry and processing fee that must be paid no less than ten days after the submission deadline.

# Lunar Control Center Station:

The Lunar Command Center is responsible for monitoring all lunar activity and occasionally directing certain lunar activities. It also ensures the smooth operation of the base and monitors the external environment. The Command Center will contain monitoring devices for all other components of the base, as well as the tools necessary to manage the following tasks:

- Direct and Coordinate Lunar Orbital and Sub-Orbital Operations
- Direct and Coordinate Orbital Transfers from Earth
- Monitor Lunar Surface Activity
    - Local Surface Activity
    - Control Monitoring Satellites
- Contact Mission Control on Earth
- Contact Other Lunar Outposts and Operations
- Monitor Lunar and Solar Environment (Notify of Hazards)
- Monitor Lunar Base Resources
    - Air
    - Water
    - Waste
    - Power
    - Food
    - Other Consumable Resources

These tasks represent the minimum required functions of a Lunar Control Center, and provide instances of many of the various curriculum topics used in classes. It is important that the Command Center at minimum has indications that all these requirements are met. For teams wishing to submit an entry for the design of the entire Lunar Base it is required that one exhibit represents the control center. Teams wishing to submit entries for more than three (3) exhibits must include either the Control Center or plans for the Greenhouse Exhibit as one of their proposed exhibits. The Control Center exhibit is intended to reinforce the idea that the exhibit is on the Moon, as well as provide an opportunity to explore subject areas that may not be easily covered in other exhibits but remain important to the $5^{th}$-$8^{th}$ grade science curriculum. A team may either design the Control Center to include some educational activity or activities based on one of the functions given above, or may create their own scenario using the core concepts of the Control Center's functionality.

**Green House Rules and Regulations**

One of the required components of the technical design contest is the inclusion of educational activities based on the lunar greenhouse. This greenhouse takes up 40% of the volume of the base and is responsible for producing all consumable organic material used on the base. It also is a crucial part of maintaining the lunar environment by producing oxygen and recycling carbon dioxide. The greenhouse activities provide the opportunity to cover topics in biology and ecology that would otherwise be difficult to cover within the context of a lunar base.

In order to properly convey the scale of the lunar greenhouse, as well as to prevent significant additional renovation expenses to the building, the lunar greenhouse will be represented in the exhibit by imagery from either an educational greenhouse (such as Tower Hill) or an industrial greenhouse. If the Tower Hill or a similar option is used, the greenhouse activities must be set in the educational greenhouse.

If an industrial greenhouse is selected, the greenhouse activities may be implemented either in an exhibit dedicated specifically to the greenhouse or in a portion of the control center dedicated to monitoring the greenhouse.

Regardless of the option selected, mission control is expected to have displays showing live footage from the lunar greenhouse, however if the industrial greenhouse is selected as the basis for the lunar greenhouse then an exhibit specifically dedicated to monitoring and maintaining the greenhouse remotely (where the greenhouse activities would take place) is also an acceptable alternative. This greenhouse exhibit, if implemented in full, must also plan some activities involving material actually present in the exhibit.

You must also choose which plants you would like to use in your greenhouse exhibit. These plants must satisfy a balanced diet for the people who inhabit the Lunar Base. Next there should also be a description of the gas exchange between various rooms, for example you should be using C3 and C4 plants when designing your greenhouse. C3 plants thrive in a high $CO_2$ environment and C4 plants thrive in a lower $CO_2$. Ideally you would want to keep your C3 plants separate from the rest of your base and somehow extract the oxygen from this room and place $CO_2$ back into this room. The list below provides plants that would be possible inclusions in a lunar greenhouse because of their growth rate, nutritional value, additional utility, and efficient use of resources to grow.

# Examples of Lunar Base Infrastructure

A truly sustainable Lunar Base must be almost completely self-sufficient. In order to sustain itself such a base would require numerous components, functions, and uses, any number of which might be adaptable to curriculum suitable for 5th through 8th grade students. These components cover a wide range of requirements, from recycling consumable resources to gas exchange and storage in the various sections of the base. The following list provides examples of the types of activities that may be suitable for the focus of specific exhibits or activities. The list is by no means comprehensive, however any additional concepts must be renewable, use only resources available to the base (or devices that may be created using the resources existing on a lunar base), and must generate sufficient value to offset the expense of their existence. For example a lunar construction yard, either in orbit or on the surface could be considered reasonable under the right circumstances; however there is almost no scenario in which livestock might be cost-effectively maintained for consumption in a lunar base environment. Teams may freely use these suggestions for the basis of their exhibits or activities and will not be deducted points by the judges for their use, however there is a small but non trivial incentive to generate and use new concepts beyond those presented in this document.

## Glassed Roads:

For any facilities not directly connected to the base proper, a “glass road” created by ***need to know exact process here*** can be used to ease travel between outposts and the base itself. These roads, while helpful, do not provide the greatest source of friction and provide an opportunity for the teaching of the concepts of motion and kinetic energy. One scenario that could be used for teaching friction is determining the speed at which a robot could travel around a sharp bend in the road without sliding off.

## Ice Mining:

One of the reasons the proposed lunar base is located in a crater at the pole is because there is strong evidence that frozen water collects in the bottom of these craters, providing the base with a large supply of an otherwise precious commodity. Given the size of the crater, such an operation would likely be connected to the main base via aforementioned “glass roads”. The ice, once extracted, will need to be transported back up the slope of the crater to the main base. This operation provides the opportunity to cover topics such as the states of matter (from melting and refreezing the ice into a more easily transportable shape such as a ball or block), potential energy (gravitational potential energy from the ice blocks being moved up the crater), and conservation of energy. The latter two concepts could be the basis, for example, for an activity in which a ball of ice breaks loose and rolls back down the crater slope towards the ice extraction operation. Such a scenario could also be used to show how a second ball of ice would stop the first, but would also result in the transfer of the first ball's energy to the second.

## Monthly Supply/Personnel Shipment:

Although ideally a lunar base would be entirely self-sufficient, this is not exceedingly practical. While would reasonably be self-sufficient with regards to resources essential for survival personnel will need to be rotated in and out of the facility and new technology (such as computer chips and other complicated pieces of modern technology) cannot be feasibly created on site. Instead the base will receive regular supply shipments from Earth. The exact way in which the supplies are raised into orbit around the Earth could be any number of things. For example the transport may launch directly from Earth's surface and return there or it may remain outside of Earth's atmosphere and act as a shuttle between the Lunar Base and some outpost in orbit around Earth. Such an outpost may be a space-station serviced in a manner similar to the ISS from which the "shuttle" would pick up its cargo or it may receive its cargo from a space elevator. The Lunar Base must have the ability to serve as mission control for this transport once it has reached the lunar sphere of influence, as well as receive and re-launch the transport.

## Orbital Operations:

In addition to tracking any arrivals or departures from the lunar sphere of influence the lunar base must be capable of tracking objects in orbit and maintaining a network of orbital communication satellites. These satellites allow the base to both communicate with any other operations on the moon and to monitor the surface conditions anywhere on the moon.

## Base Expansion:

The ultimate goal of a lunar base is to extract the relatively abundant (compared to other sources) components for nuclear fusion fuel. Helium 3 in particular is in much greater abundance on the lunar surface than anywhere on Earth. As the resources extracted at the base are increasingly demanded the original facility will need to be expanded to allow a higher production rate, including demand for more robots, personnel, and equipment. These expansion operations will require excavation, structural construction, equipment installation, and sanitation.

## Other Possible Components:

There are several other possible “additions” to a lunar base that are not required for the base to operate at a minimum. These are mostly intended to capitalize on some secondary benefit to having an existing lunar base as opposed to the primary financial-feasibility based proposition of Helium 3 collection.

One such possible extension is the existence of a scientific away base, located elsewhere on the moon that provides a laboratory for experiments that might otherwise not be feasible. An example of this might be a high-powered telescope located somewhere on the moon in near-continual darkness to shield it from interference by the sun.

Another possible extension of the base is a construction facility for large-scale projects whose mass would make it prohibitively expensive to construct from Earth. Such a construction yard might either be in orbit or on the moon, exploiting the lower energy required to escape the moon’s gravity. This facility would almost certainly construct only those components which could be assembled using materials found on the moon.

In the event that the lunar base is only a part of a larger solar system spanning infrastructure, it is likely that there would be an orbital fuel depot capable of refueling vessels bound to other parts of the solar system or returning to the Earth’s sphere of influence.

Other possible extensions include any variety of scientific expeditions to different regions of the moon. The exact reasons for such an expedition can vary greatly, however generally such an expedition must accomplish a scientific goal that is valuable enough to justify the high costs of supporting a lunar operation outside the largely self-sustaining lunar base environment.

# Why Should I Care?

## Teachers:

One of the primary goals of this contest is to create an exhibit that provides a review of and/or introduction to many of the basic scientific concepts taught in science curriculums around the country (with the focus of this contest being the Massachusetts state curriculum). The theme of a lunar base allows the exhibits to cover all range of subjects, from biospheres to motion and forces, to states of matter and chemical reactions. The exhibits allow these subjects to be presented via scenarios that would be difficult or impossible to replicate in a class room, and allows the students to immerse themselves in the theme of a lunar base.

## University Students (Contest Entrants):

This contest presents students with the opportunity to put their knowledge practical use in designing educational exhibits and activities for younger students. In addition to improving science education as a whole, and giving students valuable experience applying the knowledge gathered in classes the contest has an award pool of approximately $2000 that will be split amongst the winning entrant(s) members.

## Other:

There are many reasons to be excited about the goals of this contest. Ultimately by creating a lunar base themed educational exhibit, we intend to capture the imagination of young students and hopefully instill an interest in science that will remain for the rest of their lives. In addition to improving science education and interest in science in general, the project aims to reuse a building that would otherwise be without a purpose and provide strong financial support for the cost of renovating an aging building.

# Points Rubric

The following rubric shows approximately how heavily each part of the contest will weigh in on the judging. The rubric may change and the judges are not bound to strictly adhere to any points-based evaluation criteria but will be instructed to review entries based roughly on the points outlined below.

| | |
|---|---|
| General Use of Theme | |
| Lunar Imagery | 30 |
| Exhibit Design | 20 |
| Exhibits | |
| Command Center | **90** |
| Incorporates Lunar Imagery | 5 |
| Representation of all Command Center Requirements | 20 |
| Activities | **40** |
| Covers Curriculum Material | 10 |
| Interesting and Engaging | 10 |
| Use of Lunar Theme | 10 |
| Practicality | 10 |
| Relation to Other Exhibits | 10 |
| Use of Space/Layout Design | 15 |
| Greenhouse | **50** |
| Activities | **40** |
| Covers Curriculum Material | 10 |
| Interesting and Engaging | 10 |
| Use of Lunar Theme | 10 |
| Practicality | 10 |
| Meets all Requirements in a Practical Manner | 10 |
| Others | **50** |
| Incorporates Lunar Imagery | 5 |
| Activities | **40** |
| Covers Curriculum Material | 10 |
| Interesting and Engaging | 10 |
| Use of Lunar Theme | 10 |
| Practicality | 10 |
| Use of Space/Layout Design | 5 |
| Design | |
| Secondary Revenue Streams Protected | **40** |
| Teacher in Space | 10 |
| Weekend Visits | 15 |
| Overnights | 5 |

| | |
|---|---|
| Television Set | 10 |
| Modular Exhibits | 20 |
| Difficulty Level Modification | 20 |
| Overall: | 500 |

# Revenue Streams

## Teacher in Space

One of the alternative revenue streams for a lunar base science exhibit is the concept of a teacher in space program. This program would supplement in-class activities and lessons by providing examples of experiments or concepts from “space”. The teacher would in reality be based in the lunar base exhibit and would perform experiments or demonstrations either too dangerous to perform normally with students in the exhibit or that are too expensive, difficult, time intensive, or otherwise prohibitive. The revenue streams possible from this program would likely be a fee-based “subscription” to the concept, which would be paid by the schools who desired the material. This concept could also be extended into a Bill Nye the Science Guy type show that could be aired on network television.

## Weekend Visits

Perhaps the easiest secondary revenue stream to incorporate would be the use of the exhibit on weekends for any visitors’ use. The operational model here would be similar to a very scaled down Museum of Science (Boston). Each exhibit would have activities and/or demonstrations and there would be a small entrance fee charged to any wishing to visit allowing them access for the rest of the day. In order to ensure this revenue stream the activities must either be capable of supporting largely self-directed groups of 2-5 people or there must be secondary activities that can be swapped into and out of the different exhibits to cater to the different audiences.

## Television Set

An additional alternative revenue stream for the exhibits is that it may be used as the set for a television show. In creating a realistic model of a lunar base, there exists the strong potential for this model’s use by a television studio as a set for a science fiction show. The major attraction for a studio would be the existence of a set that has been thoroughly evaluated for realism and adherence to theme, which should result in a diverse set of exhibits portraying different parts of a lunar base. In order to ensure this revenue stream remains open there must be sufficient space in each exhibit (and especially in the command center) for a recording crew to set up their equipment. It is additionally helpful if the exhibits are modular and may be moved or disassembled if needed but this is not strictly necessary. Additionally protecting this revenue stream will require that the exhibits themselves be laid out in a manner supportive of the movement of actors and props.

## Overnight Visits

Finally another revenue stream exists in the potential for overnight visits from organizations such as the boy scouts or other special events such as birthday parties. In order to enable the former some consideration must be given to the quartering options available to personnel in a lunar base. Preferably such considerations would result in a crew quarters exhibit however such an exhibit is not required for the concept to be viable. What is required is that the overnight visitors feel immersed in a lunar base environment, even if this environment is not located in the exhibits proper. In order to protect the latter option, a mess hall as well as lunar dining must be considered.