

**A Proposal for an Educationally Interactive Exhibit based on a 2069 Lunar Base**

An Interactive Qualifying Project Report:

Submitted to the Faculty of the

WORCESTER POLYTECHNIC INSTITUTE

In partial fulfillment of the requirements for the

Degree of Bachelor of Science

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This report represents the work of one or more WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on its web site without editorial or peer review.

## Abstract

The Worcester Auditorium is in complete disrepair and the city has no idea what to do with it. This project required us to create a vision for an educational exhibit in the Worcester Auditorium's basement. We also had to develop an architectural program which described the educational exhibit for architectural students that may be interested in a contest to actually design the exhibit, sponsored by ShiftBoston. The AIAA Region 1 may also put up some prize money for the architectural student contest entrants. After the vision was complete, we presented it at the AIAA Region 1 YPSE 2012 conference in Baltimore, MD in early November. Also, we presented in a private meeting with other museum and science facility owners from all over Massachusetts in an attempt to start a consortium to submit several proposal to NASA for the 2013 NRA, which had a section that called for improved STEM in science museums and similar facilities. From an educational perspective, this was a very effective vision to teach kids about STEM through a hands on interactive exhibit. From a business perspective, it was far too much of an investment than initially suspected.

## **Acknowledgements**

**Dan Benoit, Architect, Member of Team Goddard**

**Bruce Mackenzie, Member of Team Goddard**

**Kim Poliquin, Executive Director, SHIFTboston**

**Mark Andelman, Member of Team Goddard**

**Eric Tapley, Web Designer**

**Ann Marie Pilch, Director, Tower Hill**

**Ferdinand Grosveld, AIAA Region 1 Director, AIAA**

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## 1. Introduction

The current educational system has a lot of issues that are causing kids to avoid STEM careers in the future. One issue is caused by using older teaching methods that discourage students. This can be seen in the MCAS results for Worcester where 42% of kids are in the category “Needs Improvement” or lower in STEM fields (Mass DoE). If you ask many kids about science, they feel it’s overly technical or just too difficult. These problems are a result of the way we are teaching, not the subject itself.

The current system leaves children behind and thus causes them to lack the foundation needed to understand more difficult material further in the year. Instead of dynamically scaling to the level of the children’s individual understanding and ensuring they know the material the class will move on regardless. This doesn’t just affect the current calendar year. This knowledge might not be picked up for years to come. During this project, we found out that some of our group members had some very fundamental misconceptions about science that should have been learned years ago. Unfortunately, they were not a very strong science student before college and had little motivation to learn it.

Some of us have realized now how sad that is because science can be incredibly fun to learn. The stigma with science is still that it is overly technical and difficult to pick up. This is seen in classes and textbooks that still have a focus on accuracy of words rather than familiarity with the concepts. We already simplify physics by starting with Newtonian physics. Why not do this more generally with other STEM subjects? The focus should be on engaging students with exciting learning initiatives.

Nothing is more engaging than a well-designed lab experiment. Sadly, many lab experiments aren’t experiments at all. Instead they are a set of predefined instructions that exhibit a certain effect or principle. It allows students to become familiar with equipment and see science in action, but it doesn’t let students work things out for themselves. Teachers who do this are either afraid that students won’t

be able to figure it out or they simply want to fill a lab requirement with something simple. It's also not easy to create an effective lab for one reason; creating an experiment that needs to be solved involves game/puzzle design and games/puzzles are not easy to create.

Games, puzzles, video and the internet are in the category of new teaching mediums that haven't really been explored much in public schools. The Khan Academy is an online resource that has over 1,500 videos that teach a range of topics and includes exercises (Khan Academy). There are hundreds of YouTube channels that teach various school related subjects. There are a multitude of games on the internet that introduce or solidify concepts that kids struggle with. There is classroom software that allows teachers to monitor how well their students are doing and even give extra credit to students that help other students. All of these resources and more exist, yet the most advanced piece of technology used by the majority of teachers is PowerPoint.

Our goal is to utilize all of these new mediums in an interactive exhibit to address the problems public schools in Worcester are having with STEM education and the MCAS. We have outlined a vision that would fill the basement of the Worcester Auditorium with a 2069 Lunar Base Exhibit that is educationally relevant and interactive with hands on activities based on real science.

## 2. Background Information

### 2.1 The 2007 Worcester Public Schools Science Technology / Engineering Curriculum

There are two curriculums that are currently being used as a basis for this educational exhibit proposal. One is the 2007 Worcester Public Schools STEM curriculum. The other is the spiral curriculum being developed by WPI faculty and student IQP groups, which has only been implemented for the 5<sup>th</sup> grade so far, with plans for up to 9<sup>th</sup> grade. The spiral curriculum covers a range of scientific topics while relating them to the Moon. The 2007 curriculum has certain benchmarks that teachers must address by the end of the year. Each term in 5<sup>th</sup>-9<sup>th</sup> grade follow a different facet of science. There is no unifying theme between terms. The 2007 WPS STEM curriculum was used as a foundation to the educational exhibit proposed in this IQP report.

### 2.2 Online MCAS Data

The trends in the online MCAS data reveal a few fundamental issues in our educational system. One of the more obvious ones is that about 42% of students are achieving “Needs Improvement” or lower on their MCAS science portion (Mass DoE). On a closer look, technology/engineering questions seem to be posing the greatest difficulty. This is especially true when the question is an open response. Both open response questions and technology and engineering require a strong ability to think critically, which kids are clearly not developing as much as they need to in school.

Some of the questions that kids are scoring the lowest on are about topics fundamental to their learning. A question about the difference between a compound and a mixture was missed by about 51% of the students who answered the question (Mass DoE). The question was:



*“Oxygen and iron combine chemically to form rust. Rust is classified as which of the following?:*

- A) An atom*
- B) A compound*
- C) An element*
- D) A mixture”*

The most common answer was the correct answer (compound, 49%). The next most common answer was mixture, followed by atom and then element. Low scores like this are not uncommon. Most questions were answered correctly by only less than 70% of the students who answered. Some questions were answered correctly by less than 40% of students with 36% being the worst for the state. Worcester’s average open response score was a 1.31 in 2012 with 1.71 and 1.05 being the highest and lowest individual scores, respectively. These questions are scored out of four possible points.

### 3. Literature Review

#### 3.1 IQP: A Lunar Base Exhibit Proposal

According to the research done by a previous WPI student team, Adam Savage of Mythbusters spoke, in Popular Mechanics Magazine, about a need for increased emphasis on hands on experimentation in today's classroom. (Crosby et. al.) In general, the science and engineering MCAS is viewed as negative with a need for more science equipment and curriculum reform. Approximately 60% of Worcester Public Schools (WPS) students take the SAT, compared to 90% in suburban areas nearby. (Crosby et. al.) The new idea presented is the moon as a dynamic environment instead of a dull lifeless rock. This is introduced with a technically feasible and economically viable lunar base circa 2069, and transforming this facility into an interactive and educational science exhibit for 5<sup>th</sup>-10<sup>th</sup> graders. The main functions are an interactive lab which ties to a new curriculum, a thematic and cumulative hands on component in the classroom developed by WPI IQP groups and exposure to relevant problems and solutions which impact the proposed curriculum.

Team Goddard in the 2010 Shift Boston contest developed a variety of facilities which can be used in conjunction with the lunar base to teach exciting science. The lunar sling is a theoretical apparatus which uses centrifugal force to effectively throw objects from the lunar surface towards the Earth, or into lunar orbit and across the lunar surface. A nuclear facility is located adjacent to the lunar base and has a mix of fission and fusion reactors. The principle points of this facility being helium 3 research and development for clean energy and deep space travel. The fission engines are used to drive the fusion reactions and power the lunar base. Educational and medical facilities are also a large part of the lunar base. This ties in with the human physiological and psychological implications inherent to

prolonged exposure to an isolated space environment. The idea of a classroom on the moon and virtual desks with robotic telepresence is introduced (Crosby et. al.)

Our IQP decided to focus more on the idea of a composite lunar base, which utilizes various functions and ideas as presented by many of the finalists from the 2010 Shift Boston contest revision performed by WPI IQP students. The major focuses of such a composite base are a core habitat, energy production, agricultural unit and radiation and space defense. The program developed by our IQP went beyond the scope of these objectives to include more exhibit spaces, so that the 2007 science and engineering curriculum for WPS can be accommodated throughout the entire proposed space. It is important that the individual exhibits balance details and hands on, with a focus on immersion and interactivity.

Crosby's IQP group also discovered that many WPS students were very interested in a 2069 lunar base exhibit designed with their curriculum in mind. Midland school presentations led them to the conclusion that many WPS students had persistent enthusiasm for these proposed exhibits regardless of previous knowledge or impetus. Some city requirements for the exhibit are a population of more than 250,000 with at least 20 elementary and middle schools. Worcester is approximately viable for those requirements. So given the widespread excitement for the idea of a 2069 lunar base science exhibit, the general vision by Crosby's group follows: "Improve science education while motivating students, parents, teachers, enthusiasts and professional to come together for a common goal." (Crosby et. al.)

### **3.2 IQP: Planning a Lunar Base Exhibit Design Contest**

Our initial research with the previous IQP work done by Girouard et. al. focused primarily on the design considerations, namely the required exhibits for the architectural program and the related space requirements. This IQP student group developed a lunar base exhibit contest program for our group to

use as a template to develop an architectural program. One area of major focus is the available materials on the moon and the ability for In-Situ Resource Utilization, basically a local source of materials for constructing the lunar base. This is important because importing materials from the Earth is incredibly expensive.

The idea of an exhibit space which accommodates up to 120 students was a major foundation for our architectural program. (Girouard et. al.) We developed precise timing, staffing, and student and chaperone requirements based on these initial figures. (See Program in Appendix A) The exhibit entrance starts with the little theater and an introductory video. This takes the students on a trip to the moon where they arrive at the lunar base. Once they arrive they enter the lunar base observatory and descend into the base itself through an airlock water elevator. The major exhibit space requirements are mission control, robot room and biosphere. (Girouard et. al.)

Mission control is the central hub of the lunar base. From here all other areas can be seen or controlled to a certain extent. Key information is displayed on many of the viewing screens such as local atmosphere, radiation, etc. (Girouard et. al) The suggested size is 4000 square feet with 30 students. Our group allocated nearly double this figure, but retained the ability to hold at least 30 students. In fact the proposed program exhibit for mission control can hold up to 150 people, which includes 4 classes of 30 students, chaperones, volunteers, and staff. The cafeteria and lunar classroom are also located in this exhibit adjacent to the nearby biosphere.

The robot repair room focuses on mining regolith, exploration, base construction, and building and repairing new robots. From mission control the students can view the robot repair room and get excited for the hands on activities which follow. Once they reach the robot repair room they get to physically handle the robots in several stages. If necessary, the students make repairs and reconfigure

robots for a new task. (Girouard et. al.) Next the robots are tested before they are sent off to complete whatever the designated task is. The suggested space for this exhibit is 4000 square feet and this is approximately how much we allocated in our program proposal. The exhibit space we've proposed can also accommodate up to 16 students in multiple groups.

The biosphere is the last of the required exhibit spaces as presented by Girouard's team. The focus here is on the human environment and how people will live and work on the moon. Physical implications of prolonged exposure to  $1/6^{\text{th}}$  gravity on the moon are important and a training room is dedicated to the study of those effects. The living spaces need to provide a sense of comfort and home for the inhabitants to retain psychological health. The agricultural units are also located near the biosphere. Familiar vegetation and flowering plants are common in the biosphere section for aesthetic and homeopathic purposes. The suggested space for this exhibit is around 13,000 square feet. In our proposed program we have separated the greenhouse from the biosphere and included some of the required sections like the cafeteria and training room in the larger mission control adjacency to accommodate the discrepancy in space.

Many optional exhibits are presented by Girouard's team, so that any additional space can be filled with educationally relevant and exciting spaces. We have incorporated many of these ideas into existing exhibit areas such as mission control or the biosphere. Also, additional facilities such as material processing and power generation are given their own unique exhibit space because of the educational relevance to exciting science topics that can be presented.

## 4. Architectural Program – Concepts and Imagery

### 4.1 Exhibit Concepts

The initial design for the auditorium basement space included moveable and interchangeable wall parts, which would allow the exhibit to be reconfigured for school field trip sessions and to be open on weekends for general admission. The use of projectors would allow the museum operator to show a huge selection of content in any room of the Worcester Auditorium basement without physically having to rearrange the exhibits. The content base for some of these designs can come from the local college community, along with any willing game design studio or production company. They would be commissioned to make content to be shown in 3D environments, or with an interactive nature along several of the changeable projector walls. For example, a student in a hallway could activate a size comparison exhibit using one of the consoles on the wall. They would then be able to walk up and down the hallway, experiencing the relative sizes and distances between all of the planets in our solar system, their moons, the sun, and any level of detail available to them.

Some physical exhibits pieces would have to exist, such as computer consoles, the elevators in the transportation areas, and the lunch tables at missions control. With the use of position tracking technology and projectors students would be able to interact with a massive library of content in one room while another group of students could be using the same exhibit on the other side of the exhibit. The latest design we came up with was to have static walls and exhibit spaces, with each room within the exhibit to be dedicated to one particular scientific focus; such as the materials processing and biosphere exhibits. The problem with this is that it limits the level of customization among the exhibits. If they were all going to be a static form then each exhibit would have to be much more defined, with each individual activity keyed towards a different educational experience. The introduction of special

hidden achievement easter eggs allowed us to use the original flexibility of the projector walls and interchangeable exhibits with the more rigid and defined Lunar Base Exhibit.

## 4.2 High Stakes Presentation Imagery

We wanted our presentations to visually reflect the idea of living on a futuristic moon base that was built to accommodate long-term human habitation. The base would be built from materials available on the moon, using silicates and regolith to create glass and concrete. It would most likely be a very minimalist design given our projected budget, so it would be important to focus on the size and available space rather than the conceptual technology. The original moon base models we used earlier in the project were more concept mockups, designed to show clearly the purpose of certain structures in the base. The water elevator, robot rooms, and materials processing were designed to show the main interactive features being used among the individual exhibits.

The Meridiem Luna mockups were constructed and rendered in Maya, and then the final composite was made in Photoshop. Textures were then made from stock photographs and mapped onto the surfaces of the meshes. Each image for the presentation was made using a very small selection of pre-made models that could fit together to construct any type of room, walkway, or exterior space. All Images were rendered at or above 1080p HD quality using Maya renderer 2.0, using static cameras aimed at individual scenes. Images were then cropped to fit into the 1920 by 1200 pixels, and then other elements were layered on to create the presentation. See Appendix F for the high stakes PowerPoint presentation with the images described here.

The logo design for the Meridiem Luna is based around the concepts of the primary vision of the base, which is to establish a permanent living space on the south crater of the moon, and the regolith, which would be the main = construction material for the base. The silhouettes figures in each of the

presentation pictures were added in Photoshop, having taken a selection out of a photograph and manipulating the size and pixel ratio to match the general proportions of the rendered images. The images for each individual exhibit are designed to promote the particular mission and educational goals set forth in the architectural program, which can be found in Appendix A.



## 5. Presentations

### 5.1 AIAA Region I YPSE Conference 2012

This presentation occurred in early November and had a focus on the educational aspects of the exhibits and walking the audience through what some of the exhibits would be like. A lot of people in the science field are thinking some of the ideas presented earlier in this report and want education reform. They understand that not every child was as excited about science as they were. In fact, some of them didn't start to love science until late high school or college! It was clear from the response that the vision of the exhibits was in the right direction.

After the initial presentation, we presented again to Ferdinand Grosveld, the head of AIAA Region 1, and he gave us some valuable feedback. There was one thing he said in particular that stuck with us which was loosely "Where is the fun for the children?" While I was able to explain to him what about it was fun, we realized a fundamental flaw in some of the designs of the exhibit. The exhibits need to be engaging just from a short description. In future presentations and redesigns of our exhibits, we focused on figuring out what was fun in both the mechanics and the visuals of each exhibit.

One example of these changes is in the Power and Energy room. Originally, it was simply some demonstrations of types of energy and the students had to figure out what kind of energy they were. There are no actions performed at all besides looking, making it no different from any other exhibit. To fix this, we added a whole new section where kids have to move oversized wires into sockets to finish circuits. Furthermore, the kids would have to generate the energy and put it into batteries that they would use to power the Biosphere. The result was a much more interactive and immersive experience.

## 5.2 High Stakes - STEM Educators and Target Audience

The second presentation was in C term and it was to the owners of some well-known museums and science facilities in Massachusetts. Some notable guests were the owners of the Ecotarium and the McAuliffe Center. The goal was to make them feel like they were experienced our exhibits first hand and show it would be effective if funded. The main feedback we got was that while the project itself would be highly effective, it would cost much more than the one million dollars we were looking to obtain. Just one room would have cost over four million dollars alone. We planned to have at least eight.

The most important feedback we received from this high stakes presentation was that there needs to be a business plan in place. While they are more than happy to create a revolutionary environment to help kids learn, it has to be paid for. None of them were willing to invest or even help with the project unless there was a business plan already in place. The museum industry is a very difficult and dying industry, so every dollar they spend has to have a return. They can't spend money on something risky.

The vision wasn't completely lost, however. One idea suggested was to prototype this vision either virtually or just make one room in an established museum. With this prototype, more people will be willing to fund the project. It would also allow us to find out what fundamental flaws there might be in our design.

We also discovered that this idea had been created before. In Tampa, there is a museum in place that is almost identical to our current vision for this base, called MOSI (Mosi Home). It has interactive exhibits that resemble a 2069 lunar base. Finding out the history and the business model of that location could provide a proper model for the educational proposal for future IQP groups. Based on the investment costs of the MOSI exhibit one of our team members estimated very loosely that our

proposed educational exhibit in total would require an investment of nearly 30 million dollars, as opposed to the initial one to two million figure that was given to our group at the start of the project in A term.

## 6. Summary and Conclusions

### 6.1 IQP Learning Objectives

#### 6.1.1 Technical, Social and Humanistic Context

The technical context of this report is illustrated with a 2069 lunar base that is economically viable and technically feasible with today's technology. The proposed educational exhibit suggests the use of R.F. id chips and touch screen computer interfaces for an exciting experience that students, parents, and teachers can track at any time, from any location. The technical possibilities and constraints relevant to such an exhibit, especially in terms of the physical location of the Worcester auditorium, are explored and made available for those who need to bear them in mind, such as architectural student contest entrants.

The social implications of the proposed exhibit are numerous. One example is a profound impact on local STEM education, at the elementary and middle school levels, to students in the Worcester Public Schools system. Another local effect is to improve the way Worcester welcomes citizens through Gateway park. A unique science exhibit, possibly coupled with an Air and Space museum and rentable venue, provides an exciting opportunity to expand Gateway park to tourism and local inhabitants. Right now the Worcester auditorium is barely maintained and other buildings nearby are falling into disuse, and the state of gateway park leaves much to be desired. The Worcester auditorium has a rich cultural heritage for the city of Worcester and the possibility of relating the late Professor Goddard's past research with the future possibilities of a lunar base is the proposed solution by our IQP.

Some more humanistic examples in the context of this report involve the enhancement and monitoring of STEM education, both locally and more generally, through the use of an interactive science exhibit. Such a venture requires collaboration from multiple sources who might be willing to come together for a common goal that would benefit all the players involved. The use of technology which is advanced but still affordable provides the capability to bring STEM education to the forefront of our educational curriculum in exciting and interactive ways to stimulate interest and a lifelong passion for science.

### **6.1.2 Project Goals and Objectives**

The primary goal of this project is to develop an educational science exhibit to teach and create an interest in STEM subjects, review difficult concepts that local students struggle with on the MCAS, and prompt young learners to develop a thirst for knowledge and retain the curious nature we all have from birth. Another primary goal involves presenting this vision to a variety of audiences such as architectural students, science educators, technical professionals, and the target audience – students who will be participating in the exhibit for specific educational goals in grades 5-10. The last primary focus is to develop an architectural program which uses the proposed educational exhibit in a local building in Worcester, namely the auditorium. A secondary goal related to this is to assist in the development of a web page designed for these architectural students. The web site will display the architectural programs developed by WPI IQP groups and other pertinent information to the contest, which is sponsored by ShiftBoston and funded by the AIAA Region 1. Providing additional information to a proposal for the NASA 2013 NRA is also a goal of tertiary nature. All of these goals were met with excellence by our IQP group.

### **6.1.3 Sources of Information**

The first sources of information used were the previous IQP groups that worked on the lunar base projects over the last three to five years. Some of these reports focused on the educational spiral curriculum being developed for grades 5-10 while others were more on the technical side of an actual 2069 lunar base. Within the first few weeks of A term we also reviewed local MCAS data to determine how much need there was in Worcester for an educational exhibit focused on STEM and common problem areas across the sciences. The 2007 Worcester Public Schools Science Technology and Engineering curriculum became the foundation for the proposed educational exhibit our IQP team developed as well. There are many lists of benchmarks in Appendix E that illustrate this point. Some members of our group also did preliminary summer reading on technical subjects related to a 2069 lunar base. Other members of the group developed educational research which focused on learning studies and how to present hands on education to young minds.

### **6.1.4 Selection and Implementation of methodology used for project goals**

After researching for several weeks an educational problem began to take root in our project. The MCAS data for local Worcester students was startling and disappointing, with a large proportion of students still failing science, engineering and math related questions. Other research by previous IQP groups and in the literature suggested that STEM interest and a passion for science was also on the wane. At that point it starts to become clear why the U.S. is struggling to turn out a dedicated and well educated technical citizenship which is well equipped to solve problems in the 21<sup>st</sup> century.

The solution methodology developed to combat these problems is simple. First we take the 2007 WPS curriculum and rethink how to present the material, especially the most relevant problem areas on the MCAS and in general science learning. The major focus of the educational exhibit

developed by our team is to use advanced technology to make things interactive and exciting, but also use physical objects for hands on activities to illustrate real science, albeit in a simplified manner. The difficulty for the science education goals can be scaled to the students as they learn in order to provide more or less challenge as necessary. The central theme is a 2069 lunar base where actual science problems are presented in the form of exciting and challenging games, where students work together to learn and discuss their results.

#### **6.1.5 Analyze and Synthesize results from other perspectives (technical, social, humanistic)**

We learned to think about critical selling points of our exhibit from Eric Tapley, a local web designer brought in to help develop the web page for the architectural students. His desire to present information in a simple, basic and powerful format allowed us to really bring the main points of our exhibit to the architectural students. This result provided us with a better understanding of social expectations with one of the primary audiences. By developing presentation pitches for a variety of audiences we learned how to develop a presentation style which incorporates the moral and ethical paradigms of many different sources. The little theatre in the Worcester auditorium has a rich cultural heritage, as does the WWII memorial, and rethinking how to use these areas for our exhibit taught us about humanitarian points of view. For example, we had to answer the question: "How do we use the little theatre to make 5<sup>th</sup> graders feel like they are on a spaceship traveling to the moon?".

The AIAA Region 1 sponsored Young Profession and Student Educators conference we attended in B term taught us about technical and educator perspectives. The technical audience raised questions for our 3 primary exhibits at the time, mission control, robot room and materials processing. This information was valuable to the continued development of these and other sub-exhibits in the proposal for an educational science exhibit. The educators were pleased to see us reference educational

benchmarks and this affirmed our methodology to use the 2007 WPS curriculum as a foundation to our project.

#### **6.1.6 Maintain working relationships with team members and project advisors**

From the start of this IQP project our team had few problems and synergized very well together. All team members got along with each other and with the project advisor, Professor Dempsey. Group meetings were pleasant with a mix of professionalism, productivity, and humor. As a team we developed the goals for our project throughout A and B term with little need for direction from Professor Dempsey, although he was instrumental in providing quick feedback for technical documents or other concerns we had in general. Towards the beginning of C term there was a need for group member evaluations because some members had struggled with periods of high stress at some point throughout the project. At the end of the project the overall contribution from all team members was equivalent, with each member experiencing their own respective periods where they had to rely on the group as a whole. This was a valuable lesson for all of us in the sense that we learned how to ask for help and work as a team. Together our group was able to meet and exceed all of the expectations set forth by both project advisors Professor Dempsey and Professor Wilkes, to accomplish the project goals.

There was also another project group similar to ours that developed an educational science exhibit for the Worcester auditorium under the guidance of Professor Moriarty. Professor Wilkes also lead a group of students who developed the 6<sup>th</sup> grade spiral curriculum component and provided management for the other project teams. All of these student groups routinely presented to one another before the YPSE 2012 conference and before the high stakes consortium meeting. We were able to give each other valuable feedback and these experiences helped us learn how to work with a more diverse set of people. Through comparative analysis of other groups' presentations we were able to



learn more about what was expected of us and develop excellence in presentation experience. Professor Wilkes, in addition to leading the management team, was always available to meet or discuss via email the numerous concerns our group had throughout the project. He also got us some one-on-one presentation time with Ferdinand Grosveld, AIAA Region 1 director, at the YPSE 2012 conference. Professor Dempsey presented to all the student groups on the Worcester auditorium. Professor Moriarty presented a business plan with several models at the high stakes consortium presentation and was also available to provide information on his experiences with the McAuliffe center and how they related to our project. Having multiple professors and student groups to work with was a very unique learning experience and this IQP has given us an incredible opportunity to develop team-building and social skills.

#### **6.1.7 Demonstration of ability to write clearly, critically, and persuasively**

Appendix A is the architectural program developed by our IQP group. This is an example of clear, critical and persuasive writing that our team developed for the project. The two presentations listed in Appendix F are also strong examples of persuasive writing ability.

#### **6.1.8 Demonstration of strong oral communication skills using visual aids**

Appendix F shows both the high stakes consortium presentation and the YPSE 2012 presentation developed by our group for this project. These two presentations are excellent examples of strong oral communication skill using visual aids. The high stakes consortium presentation was also video taped and is going to be available on the web page being designed for architectural students.

### **6.1.9 Demonstrate awareness of ethical dimensions**

This project taught our group to develop a presentation style for a wide variety of audiences such as educators, technical professionals, architectural professionals and students, a general audience and the target audience – students in grades 5-10. The style and pitch developed for a particular audience focuses on the implications and effects they would anticipate. The plan for an exhibit space incorporated the views of all these audiences in order to work towards a common goal. These efforts require teamwork and communication from persons with very different moral and ethical backgrounds.

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## 8. Appendices

### Appendix A – Architectural Program

#### Chapter 1 - Introduction

##### *Vision*

The future of the aerospace industry is uncertain as 25% of current professionals are approaching retirement age. This interactive and dynamic educational exhibit based on a circa 2069 lunar base, feasible with today's technology, could be a step towards restoring an educational pipeline required for interest in aerospace. This exhibit also seeks to support interest in STEM<sup>1</sup> sciences and other multidisciplinary fields. The problems of tomorrow require a diverse, team-oriented approach to learning, which the exhibit aims to provide, and conventional classroom models typically fail to achieve. Science is often portrayed as a complex and boring subject, but this exhibit aims to restore the sense of wonder and curiosity people tend to lose or discard over time. An added benefit is reshaping the general image of the moon as a place which is both resource rich and has the potential for advancement across many disciplines.

The core educational concept of this exhibit proposal is a series of exciting, interactive, and educationally relevant exhibits one can find in a technically feasible lunar base. The goal is to design exhibits where kids solve problems together with little help from staff. Every problem will have a theme, each of which is a room that appears on a 2069 Moon base. The exhibits are designed from the ground up with Worcester Public Schools (WPS) 2007 Science, Technology, and Engineering Curriculum as the foundation. Review of concepts for MCAS and other mandated exam requirements (for out of state students) are also taken into account. A spiral curriculum being developed by WPI students for grades 5-9

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<sup>1</sup> Science Technology Engineering and Mathematics

in WPS also results in a capstone experience and review component the students experience at the proposed lunar base exhibit.

Each exhibit is designed around relevant scientific topics for grades 5-9. Members of staff are also encouraged to go above and beyond if groups of students are interested in a given topic in greater detail. Each exhibit is a dynamic environment built for the specific academic needs of the students and their grade levels. For example, a 5<sup>th</sup> grade unit in the Robot Room focuses on the very basics of engineering and design, and when the students return again in 6<sup>th</sup> and 7<sup>th</sup> grade the topics are more advanced, and this correlates to the curriculum requirements. This process is followed throughout the entire exhibit, and each space provides a learning environment for any grade level, building directly from curriculum requirements in fun and exciting ways.

### *Element Sizes – Design Requirements*

The total available area of the exhibit design space in the basement of the Worcester Auditorium is approximately 37,000 ft<sup>2</sup>, as shown in figure (1). The dots represent pillars that are part of the building and must be incorporated into the lunar base exhibit design. The pillars can be used as structural elements that are made out of iron and steel, which represents a local construction material available on the moon.

Individual exhibit space requirements are suggested in Table A.1 in the appendix. These space requirements are flexible within a range of about 10%. Mission control is the largest area, being the central hub for the base. Figure (2) is a blueprint for each exhibit and where they are located relative to one another, and the base entrance. Sublevels are color coded. Approximately 5% of total space is allocated for supporting areas such as for the employees and mechanics that run the exhibit.

### *Element Adjacencies – Design Considerations*

Students go downstairs from the little theatre and enter the lunar base observatory. This is equivalent to going down a set of stairs on the lunar surface to an airlock entrance into the first sublevel located 10 meters below. This is the only real level change in the exhibit. The auditorium basement is flat and cannot emulate a lunar base built into a crater with multiple levels. To simulate the effect, there will be an elevator that spins in place (More details later). On sublevel 1, students find mission control, the biosphere, and the agricultural swamp. Mission control elevators connect to sublevels 2, 3, and 4.

The robot room and material processing are on sublevel 2. Water processing and power and energy are on sublevel 3. Sublevel 4 is an emergency bunker for solar flares, and also functions as a futuristic 3D projection room for holographic exploration. A detailed flow diagram can be seen in figure (3).

### *Element Flow - Student Experience*

The students' journey begins in the little theatre where they see an introductory movie. They journey to the moon where they have been hired by Lunacorp (which has a NASA contract to operate on the lunar base). Of the 1000 earth based operatives these students are the elite 5% that are chosen to actually go to the moon. The students descend into the lunar base observatory and enter mission control via stairs outside the little theatre. From mission control the students are broken up into 8 groups and go to the 8 main exhibits. Exhibit flow is from mission control to the agricultural swamp, and then biosphere. Next an elevator connects sublevel 1 to 2 and flow continues to robot room and material processing. Another elevator connects sublevel 2 and 3 and flow continues to water processing and power and energy. Another elevator in mission control connects to sublevel 3 for when students need to meet back for lunch in the cafeteria (located in mission control). After power and energy the students take an elevator down into the future room and then return to mission control via one final elevator ride. This cyclical process is shown in greater detail in figure (4).

The flow is setup to emulate a lunar base built into the side of a crater located at the south pole of the moon. Plants, humans, and working areas are on the highest sublevel of the base, where pressures are lower and natural light more intense. Robot room and materials processing are on sub level 2 so robots can be distributed all over the base and to the lunar surface. The water in the perpetually dark core of the crater has to be transported up to the lunar base, so having water processing on sub level 3 is an important design characteristic. Power and energy is also located on sub level 3 for safety and protection from radiation and asteroids.

### *Occupancy – Target Audience*

A detailed table of the timing involved is provided in Table A.2. An estimated 120 students, or 4 full size classrooms, can be accommodated by the exhibit in a single day. The students are split up into groups of 14-16, based on total individual class size. Each of these groups has 1 or 2 chaperones, which can be parents or volunteers through the respective school. Chaperones facilitate the students' discoveries by working with the exhibit staff as the field trip progresses.

### *Timing – Exhibit Events*

The exhibit assumes a full day field trip with the students arriving at 9:00 am and leaving at 3:00 pm. Lunch is provided in the ticket cost, but parents and students still have the option of bringing their own meals. A cost differential for those supplying their own food exists so that a non-meal ticket is \$5-7 cheaper, perhaps \$10 vs. \$16 but the lunch provided is designed to mimic food that is only available on the lunar base. For example, no cow's milk or meat products but a diet based on what can be grown in greenhouses and fish tanks. An equal amount of time is allocated for each of the exhibits. A discussion session at the end of the field trip focuses on the student groups presenting what they learned to each



other, with the assistance of the staff guides and chaperones. This is also where all of the easter eggs discovered are discussed (more on that below).

### *Staffing*

The lunar base exhibit is staffed by an estimated two dozen employees, with about half of them being volunteers or federal work-study college students. The ticket booth, gift shop, and information areas are located just inside the auditorium via the little theatre entrance side. The lunar base themed gift shop provides a source of income for the exhibit initiative. Each of the exhibits has a guide while more extensive exhibits have someone working in the background of the machines and devices. For example, in materials processing there is someone taking the materials the students put into the machines and returning other items based what the students do. A detailed table of the staffing requirements can be found in Appendix A.3 at the end of the program.

### *Easter Eggs Concept*

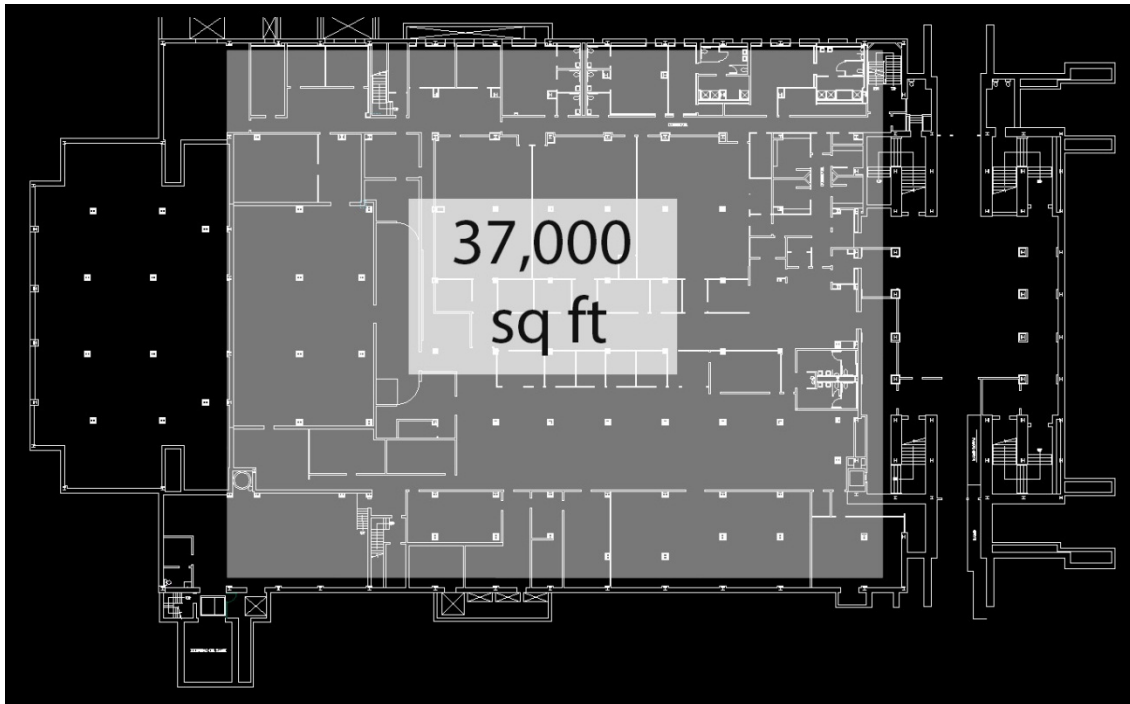
Easter eggs are a term in video game design defined as any event or item that is purposely hidden so only very observant players will find them. Their discrete nature breathes life into games for a few reasons. Levels that were once considered complete have a whole new element to them when an easter egg is discovered or heard about. Those few that discover them on their own get bragging rights. The true power behind them is they encourage players to want to explore the world beyond what is just right in front of them.

We want to carry this concept into each room in the exhibit. At the start, everyone will learn that each room has one hidden hand sensor they can find. When they touch it, an announcement will tell everyone in the base that an easter egg has been discovered. With each easter egg, there is something special to learn about the base. For example, the material processing room has a vat that takes elements/compounds and produces what would naturally result from them. Water mixed with sodium is extremely volatile and

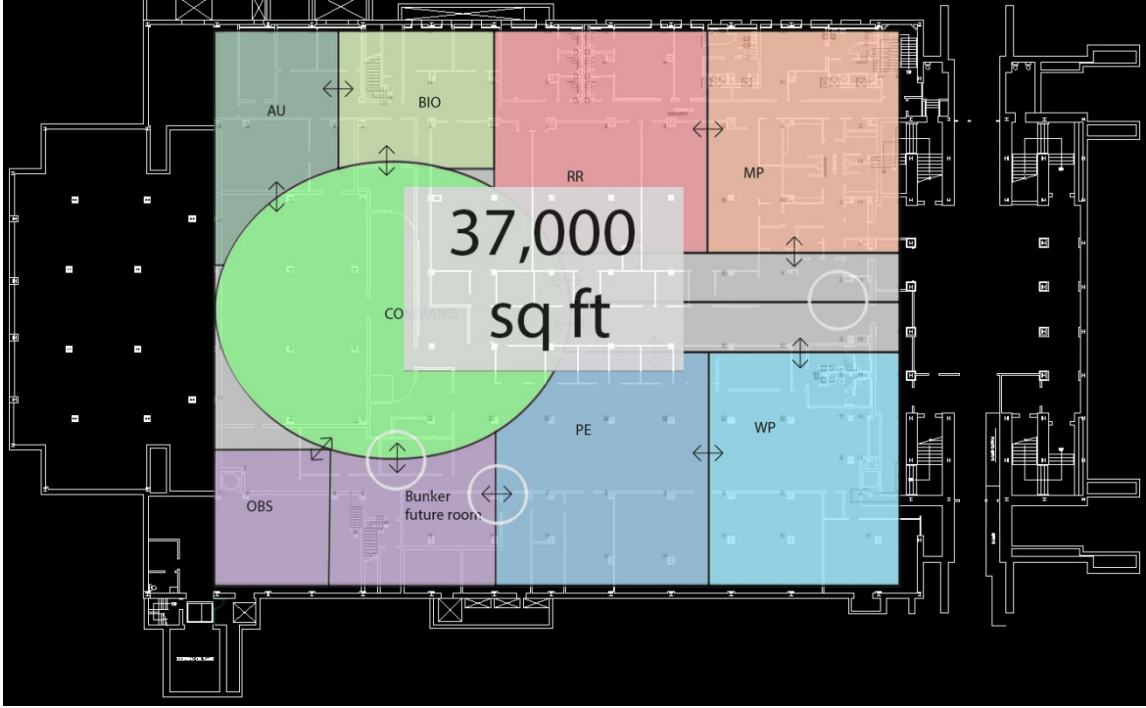
will immediately cause an explosion. If the students mix these two together, a fake explosion will occur in the vat. This is quickly proceeded by the screen turning into a hand sensor. Once it's touched, the RFID chip in the student's bracelet will be read and the easter egg announcement will be activated. Every student will hear "An easter egg has been discovered! Apparently, mixing water and sodium does NOT make saltwater!" Easter eggs like these will be available in every single room.

## Chapter 2 - Imagery

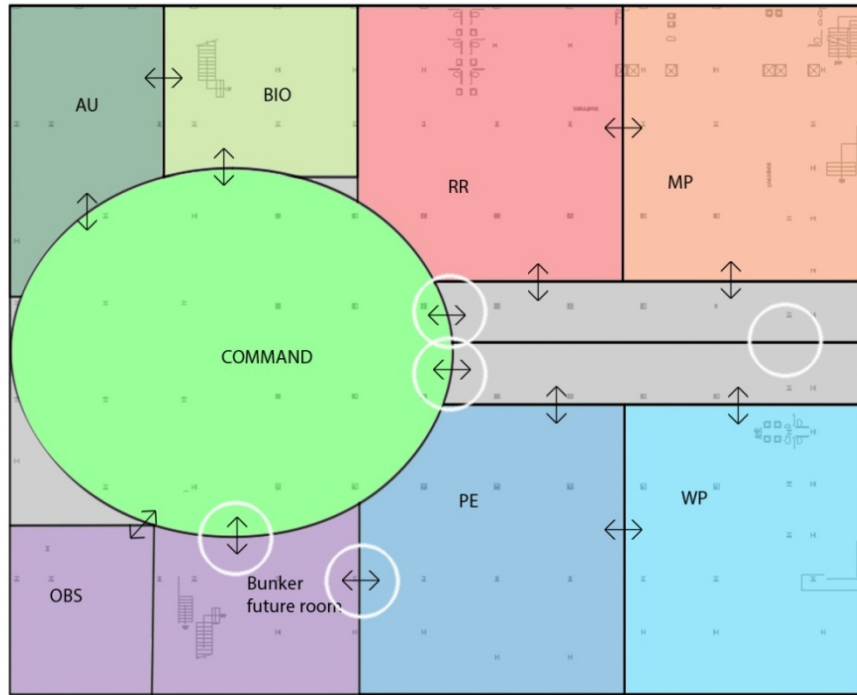
This chapter focuses on imagery for the overall exhibit and how it fits into the design space requirements.



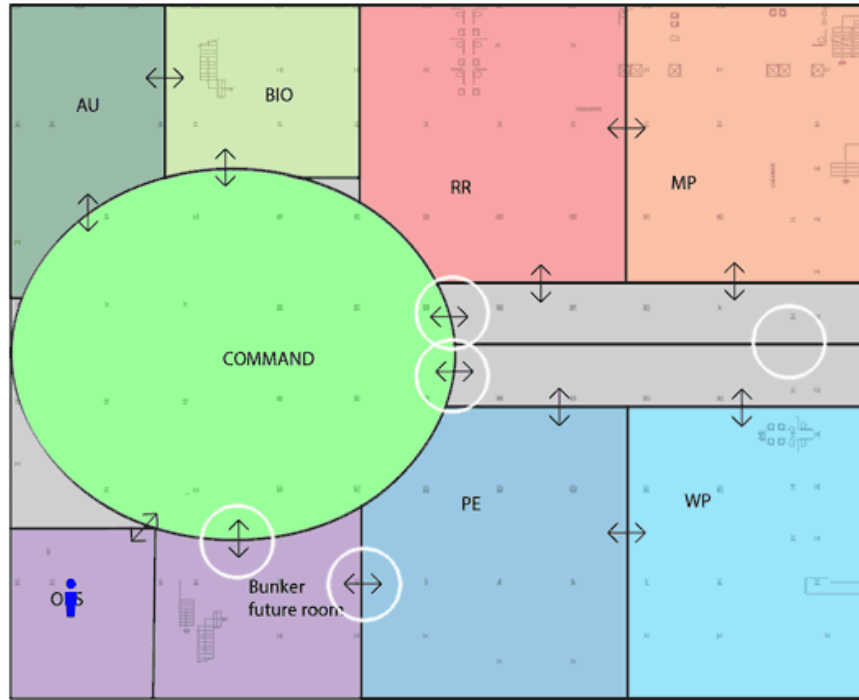
**Figure 1 – Available Design Space in the Worcester Auditorium Basement**



**Figure 2 – Blueprint of Proposed Exhibit Superimposed on Design Space**



**Figure 3 – Element Flow**



**Figure 4 – Element Flow GIF**

## Chapter 3 - Exhibits

This chapter will focus on each individual exhibit. Each exhibit is then divided into three main sections:

**Experience:** This is the experience the kids will have from the moment they begin interacting with the exhibit until they leave. All technical details are left out of this part.

**Architectural Considerations:** These are the more important considerations of each room. These are what separate one room from another and require a bit more attention. Our hope is that these are the exciting bits.

**Other Details:** These are important details that don't necessarily separate this room from others. This might also have some more scientific knowledge if it is necessary for the understanding of the room.

### *The Little Theater Introduction*

#### **Experience**

The students enter the base and each one gets a small bracelet. Inside each bracelet is a small RFID chip to allow them to interact with the exhibits. They enter what looks like a massive space-like theater. There's a large screen that starts playing once all of the students are seated. The movie begins by welcoming them to the team at NASA (Lunacorp) and congratulating them on being chosen as part of the few who get to live on the moon for a year. After a quick introduction, they'll be watching a first person view of them all going into space. On the way to the moon, someone will be at the front explaining what exactly is in and on the moon base and where they can choose to go first. This room is where the students will learn about easter eggs. The presenter will tell the students to check under their seats for the easteregg pad. It'll play the fact through the speakers and then an announcement will occur. After they dock, they'll head downstairs.

## **Architectural Considerations**

This is the key moment that has to excite the kids about not only the exhibit they find the most interesting, but get them to anticipate the experience and become fully immersed. The inside of this theater needs to feel like a giant futuristic spacecraft and the students are riding it into space. Should it be economically feasible, any additional immersion capabilities available are to be implemented. Some ideas are shaking seats, 3D video and high quality speakers to simulate the thrusters of a real spacecraft.

## **Other Details**

There needs to be enough seats for about 150 people. The room in its current state can hold almost 300 people on just the bottom floor. Thus, the focus can be more on immersion rather than finding room. Cargo can fill empty seats and the entire theater is redesigned with temporary props, walls, etc. so the students feel like they are in a spaceship traveling from Earth to the Moon.

The easter egg will tell the students that the moon will always face the Earth because it's shaped slightly like an oval. The announcement will say "Someone has just discovered that the same face of the moon is watching us. Always watching." The introduction also takes the students in orbit around the moon so they can see the dark side as well.

## ***Mission Control***

### **Experience**

Mission control covers concepts such as the extraction, storage and use of lunar materials. Other concepts include: communications and trade between the lunar base and Earth, the commute of the lunar base inhabitants between adjacent facilities and orbital stations, and how the base conducts its internal business such as power requirements and scientific experiments. Visitors experience the multi-level layout of the

base even though the Worcester Auditorium basement is a single level. Mission control is communicating with various places on the moon and Earth, and real-time feeds from other museums or facilities might be used in this exhibit for specific illustrative goals. An example is a robotic camera feed located at one of NASA's Lunar Testing Facilities.

Mission control is the central hub of all other exhibits in the base, and is connected through the water elevator airlocks and networked with various computer consoles and interactive touch panels. Visitors go on virtual missions, and learn about the scientific concepts which make the day-to-day operations of a lunar base possible. The "teacher in space" lecture hall and cafeteria are also located in mission control, nearby to the biosphere facilities. These sections can be multi-purpose and hold up to 300 people. All students return to this area in the middle of the field trip for a lunar base style luncheon.

### **Architectural Considerations**

The central area of the base is the monitoring, communications and management portion, and the exhibit reflects its connectivity to all the other areas. Since there is a 3 second delay for robotic teleoperation from Earth, the majority of control that needs to be precise and timed is performed in mission control. The entire room is networked with various computers and monitors, and has the space necessary to hold up to approximately 120 people at once.

Mission control connects directly to three separate elevators, and is organized to filter groups of students through the exhibits at staggered rates, while still allowing them to experience the entire command center.

### **Other details**

The control room has several consoles which allow students to manipulate the bases internal and external environments. They can also experience portions of the base that aren't necessarily covered in the main concept, such as fusion power facilities, transportation infrastructure (glass highway), and the lunar sling.



The mission control area is associated with business concepts and financing of the lunar base. Oxygen and helium 3 are harvested from the lunar regolith. The oxygen is exported to low earth orbit in condensed liquid form (LOX), while nitrogen and possibly hydrogen are imported to the moon from Earth. Helium 3, which is a vital research material for fusion reactor technology, is exported to the Earth's surface where it is in short supply. Export products are shipped to Earth using the lunar surface sling, which takes advantage of the moon's low gravity and centrifugal forces to avoid burning fuel and kicking up dust all around the lunar base and adjacent facilities. Propulsion from an arbitrary launch pad results in dust clouds being kicked up and circling the moon, possibly settling in places that are problematic for robotics or other machinery. A microwaved glass launch pad, however, allows the propulsion of systems from the lunar surface with limited dust kick-up.

The easter egg will be in one of the wrappers from the food that is provided for the students. If they bring it up to the food staff the easter egg will be activated.

### *The Water Elevator*

#### **Experience**

The students enter the water elevator air lock from one side. The doors close behind them and an automated voice start telling them random facts about the base. There are also some large touch screens that include small stories about events occurring on the moon such as sports games. Once the elevator has gotten to the correct level, the students will exit out *the same door they came in*. The main water elevator air lock, which provides entry to the lunar base from the lunar surface, balances the interior pressure of the base (between 0.5 and 1 Earth atmospheres) with the vacuum pressure (0 atmospheres) of space on the surface.

#### **Architectural Considerations**

The idea behind this room is to simulate levels of a base that aren't really there. When they enter the elevator, there are only two levels it can really get to: The current level and the target level. The other buttons are just there for show. To allow for the students to exit out the same door they came in, the entire elevator will have to spin around 180 degrees but slowly. The doors of the elevator will need another door that blocks the view of the people looking at the elevator from the outside. This is to prevent them from seeing the elevator spin.

### **Other Details**

The easter egg in this room is on one of the news stories. If they open a story about a space soccer game. Space soccer occurs in a sphere. Because there is 1/6th gravity, players would be able to float around, extend their leaps, and bounce off objects. Once they read the story about who won the game, an announcement will say "Someone has discovered the COOLEST sport ever. EVER!"

There will need to be enough screens for about thirty students to all have something to read about. If possible, these screens could be fully interactive and voiced news stories discussing activities by people on the moon or operating from back on Earth.

## *Agricultural Unit*

### **Experience**

From mission control or biosphere, students enter the agricultural unit through a small hallway that takes them into the center of the exhibit space. This section has terminals that control the environment of the agricultural swamp that surrounds them. Upon entering the agricultural unit students receive gas masks to protect them from semi-toxic levels of CO<sub>2</sub>. The higher concentrations of CO<sub>2</sub> enhance the growth rate of plants that evolved in earlier epochs when mammals were not dominant. The center room has a reflecting mirror that receives light from up on the lunar surface. This central reflection mirror diffracts light to eight modular growing units set up around the tower in an octagonal array. Students learn about

the plants in these different sections and control the environments through a GUI and touch screen interface. Three aspects of the plant environment students control are water, light, and gas exchange. The goal is to provide each unique plant or animal section with an optimum level of these parameters. The simplest level of the environment requires the students to physically rotate a cylinder with light pouring out over the plants, in order to provide a certain percentage of light. More complex levels require virtual control of water, gas content, and timing of all controllable parameters, namely light, water and gas.

### **Architectural Considerations**

The central light tower reflects light down to provide the agricultural unit with natural sunlight. Modularized design allows the unit to house more varieties of plants and animals while still optimizing their growth and yield. An example of 1 section is a cattail swamp, which also acts as a natural water filtration system for water (The Incredible Cattail).

### **Other Details**

The modular units can contain varieties of plants or animals so that multiple sub-groups of students work on their own respective tasks at the same time, and can also switch off or rotate as they finish. The plants provide food and vital materials for the lunar base. Animal labs are also possible, by removing 1 or 2 sections for plant growth and replacing them. Many materials are produced from plants grown in the agricultural swamp. Cat tails and taro provide sugar, starch, flour, fiber, and stalks that can be used for bows and arrows (The Incredible Cattail). Archery is a potential lunar sport. Having 2-3 subsections dedicated to a swamp-like environment also provides an additional filtration method for waste water produced in the biosphere. The gas masks available to students are aesthetic and the room will not actually be harmful. Plants which are more sensitive to oxygen experience photorespiration, so being able to directly control the environments of modular growing spaces is important.(Andelman 262-269) Each

unit has a parabolic reflector above and this receives light from a mirror which receives light from the central diffraction tower.

The easter egg for agricultural is a unique plant that some students may discover. A super potato grown with the right amount of light, CO<sub>2</sub>, and Oxygen will unlock the announcement, “Congratulations, you have discovered GLaDOS, the super potato!”

## *Biosphere*

### **Experience**

The biosphere introduces the concept of a human environment which is part of an interdependent gas exchange system with the plants in the green house and the various gas and water exchanges throughout the base, from material processing to water processing. Experiences range from an explanation of what is required for lunar base inhabitants to survive to the social amenities provided for them to keep in touch with friends and family back home on Earth.

Visitors are going to explore lunar apartments, media players, fitness areas and medical facilities. They are directed to complete repair missions, participate part in lunar sports, or assist in the construction of additional segments to the lunar base. A specific example is continuing the circumferential construction of a lunar base built into the side of a crater located at the south pole, namely Shackleton.

### **Architectural considerations**

The biosphere has rooms dedicated to medical, physical, and mental health considerations. Dietary requirements and entertainment facilities are crucial to a happy and productive crew. The lunar apartment is important to show exactly how inhabitants work and live in a low gravity temporary environment, but many other areas can be multi-purpose. Examples include exercise rooms combined with medical, and the educational with recreational.

The individual and group living quarters are designed for low gravity storage spaces so, for example, a bookcase or closet can be towards the ceiling on the higher sections of the walls. The majority of apartments are modular so groups or families can be accommodated comfortably. Additional modularity exists so media players and exercise spaces can be incorporated to suit individual need.

### **Other details**

The biosphere is about living on the moon and building and maintaining a homeostatic environment that sustains and accommodates human life. Physical exercise, mental stimulation, and regular medical checkups are required in order to live in a low gravity environment for extended lengths of time. The gas exchange system for carbon, oxygen, and nitrogen is important to a 5<sup>th</sup> and 6<sup>th</sup> grade curriculum, but more complex dynamics are also available for teaching higher grade levels, or for more general knowledge.

The Biosphere is more open than the majority of the lunar base so the easter egg here will be one of the hardest to find. An activities room will have many lunar themed sports that the students can play, such as rocketball (a sort of 3D rugby). If the students get some points in this or another sport, it will activate the easter egg announcement. Many of these lunar sports will be simulated using GUI, since low gravity would be required and in actuality these sports would be far too dangerous to emulate without the proper facilities.

### ***Robot Room***

#### **Experience**

Students entering the robot room hear sounds from nearby information terminals. The terminals provide students with a list of semi-autonomous robotic tasks. Information on the requirements and science related to each task is made available with a web page interface. These instructive modules are designed

around specific grade levels, using simplified physical models and examples. After selecting a task the students go to one of the robot repair and construction stations. Here, they recondition, reconfigure or design a robot with a hands-on robotics kit, such as LEGO Next (The LEGO Group) or through a virtual program. A guide in the room encourages the students to think of ways to best repair, reconfigure or design their prototypes. The next station is a robot testing area where the students test their design on task specific obstacle courses, and like the robots, they are physical or virtual. Multiple obstacle courses accommodate sub-groups of students working in the robot room. Students are exposed to engineering decision making as they test and reconfigure their robot for the chosen task. Once the students finalize their prototype, the robot exits the room to prepare for its task. Next, students operate the robots through telepresence on touch screens with a GUI. These terminals are set up for groups of students to work together and discuss their results.

### **Architectural Considerations**

The student work stations mentioned above are equipped with built in touchscreen interfaces. Students are able to remotely operate the robot through these interfaces with a GUI. Each student in a group is responsible for particular components of the robot, such as wheels or arms. The robotic tasks are designed around specific grade levels 5-9, but general activities are also possible for other audiences. Specific capstone experiences for WPS students in 7<sup>th</sup> and 8<sup>th</sup> grade are a major focus with the WPI lunar-themed spiral curriculum.

### **Other Details**

#### ***Available Tasks:***

- |                       |                   |
|-----------------------|-------------------|
| 1 Regolith Collection | 7. Expanding Base |
| 2 Surface Surveying   | 8. Handling Water |

- |                               |                                    |
|-------------------------------|------------------------------------|
| 3 Off-Site Robot Repair       | 9. Gas Exchange System Maintenance |
| 4 Off-Site Robot Construction | 10. General Maintenance            |
| 5 Exploratory Drilling        | 11. Agricultural Unit Maintenance  |
| 6 Expanding Infrastructures   |                                    |

Additional space is devoted to a robotic “memorial” or history exhibit that describes the evolution of the lunar robot. The base and all 1st generation facilities are predicated on a biological growth robotics kit being sent to the moon, perhaps by 2020, in accordance with Von Neumann’s vision. (Morin 6018.pdf) The “Moonraker”, winner of the NASA Centennial Prize and designed by a WPI student team, makes an excellent possible addition.

The easter egg for the robot room is unlocked if a group of students discovers and decodes a hidden sound message through GUI capabilities of their robot. This sound message is located somewhere near an objective for performing a task, so students willing to explore might find it. The announcement, “Great job, you’ve discovered the remains of a crashed 20<sup>th</sup> century lunar probe!” follows.

Again, remember that there needs to be enough robots and obstacle courses for however many groups there are. This room will have at least fourteen students coming into it. They will be split into groups of three or four.

### *Material Processing*

#### **Experience**

The goal of this exhibit is to empower kids to experiment with the tools that are around them to achieve goals related to chemistry. The students are considered to be the new batch of lead scientists in the material processing unit. Their task is to figure out how to make various elements and compounds from

the materials of the moon. The materials will come from a machine that drops various types of regolith and water in the form of briny ice or dry water. These plastic vials will have the elements' symbol on the top, but they will not have the full name. They'll have to identify them on a large periodic table, which will light up the element when they have found it. To separate and combine these materials, they'll put different combinations of them into the other three machines: the melting vat, electrolysis machine and condenser.

### **Special considerations**

In order to allow the kids to combine and separate the plastic vials, the melting vat will have to be connected to a back room with all of the available combinations. The person in this back room will then retrieve the correct materials and send them back to the students. From the students' point of view, the materials will go into one end of the melting vat, they'll see the plastic vials in what appears to be lava and they'll hear all the sounds a melting vat would make. In reality, the lava is just a monitor playing a video at the appropriate time. Each plastic vial will have an RFID chip on the inside, allowing the melting vat to identify what materials have gone in. RFID chips are particularly inexpensive (0.50\$ each) and there shouldn't be much of an issue getting one for every plastic vial (Bret).

*Note: Every machine will have to have functionality similar to this, respective of what the real version of the machine does.*

### **Other details**

Each plastic vial will need to contain a fluid, gas or solid that represents the item inside of it. These plastic vials will also need to not only be unbreakable, and not open able. None of the materials, besides water, would be the real element.



The room also requires a display to let the students know what their next goal is. For example, the first one will most likely be to figure out how to get water. The display would say something simple such as “Goal 1: Create water.” Once they figure out how to make that goal, they will get another goal such as “Goal 2: Create rocket fuel (liquid O<sub>2</sub> and H<sub>2</sub>)” Each of the machines would have a display as well that indicates what elements are in the machine and what the result will be.

The last piece is the easter egg in this room, which comes from the students mixing water with sodium. If they do this, the melting vat will make a loud explosion sound (as real water and sodium would do). The melting vat should also release a bit of water vapor from the mixture.

### *Water Processing*

#### **Experience**

The majority of the bases clean water is stored in water processing, so before students enter they are “decontaminated”. The process can be simulated using computer software and fog. A computer voice explains the purpose and process of decontamination as it happens.

One goal for the students is to take lunar water and remove the salt. This is accomplished through a virtual desalination machine with reverse osmosis or capacitive deionization. The students learn how to remove the salts from the water and test it after they are done. The testing part can be done with real water and PH strips, with various levels of salinity depending on how they perform with the virtual activity. Another goal is to take the physical principles related to plumbing, civil engineering, and various water properties to teach the students about Archimedes principle and pressure forces. A virtual activity has students learning about the manometer tube design of the water elevator air locks. They can also learn about volume displacement of an object in a liquid and simple pressure relationships for hydrostatic pressure over a surface. A virtual plumbing terminal shows the students how a complex and dynamic

system provides clean, drinkable water for the lunar base. Sub-groups of students rotate through each of the experimental activities.

### **Architectural Considerations**

The decontamination entrance is an immersive way to introduce students to water processing. The large water storage tanks have thick glass walls. The students can see into the tanks and nearby information terminals which describe the properties of clean water, such as PH or salinity. A GUI shows students how the clean and waste water travels throughout the base, and they can interact with it through a touch screen interface.

### **Other Details**

Additional storage tanks are located in the biosphere and at off-site facilities. Waste water treatment machines involve the recycling of human and animal waste in water processing. In addition, some waste water can be filtered through the agricultural swamp. Water filtration machines are used for the recycling of gray water and are also located in this facility. Some examples of gray water include run-off from dishes, laundry, showering, and general maintenance.

The desalination process requires different methods. Two available technologies are reverse osmosis and capacitive deionization (Andelman 262-269). A water distribution terminal with a touch screen interface shows students where the water in the base is going. The focus is on a Closed Environment Life Support System, or CELSS (Morin 6018.pdf).

In some countries people consume up to 6 liters of water per day. An old toilet consumes 3 times that in a single flush. This information is presented to the students as an easter egg when they flush a toilet in the bathroom in water processing. “Congratulations, if this were a conventional water flushing toilet you just used, on average, the daily water supply for 3 people.”

## *Power and Energy*

### **Experience**

The students will enter the room and be introduced to an intern who is supposed to be working with the energy systems. They find out that half of the biosphere will lose power in the next thirty minutes if they don't figure out what he did wrong. The intern will read the notes left by the scientist who got reassigned and find out exactly what power and energy is (in very basic terms). With this new knowledge, they will attempt to find as many ways as possible to generate energy for the base. After they have enough energy stored, their goal becomes working the wires to route that energy to the biosphere. There are different circuits that lead into the biosphere and students pull out and move oversized plugs to try and complete the circuit. At the end, they find out if they completely saved him or not.

### **Architectural Considerations**

Here are the answers:

#### ***Kinetic Energy***

- i Electrical
- ii Thermal
- iii Electromagnetic
- iv Sound
- v Motion

#### ***Potential Energy***

- i. Chemical
- ii. Elastic
- iii. Gravitational
- iv. Electric
- v. Magnetic
- vi. Nuclear

*Energy is something that is moving or something that could move.*

The sentence above is the explanation the children will get for energy. Some examples of ways to generate energy are objects the children need to rotate, batteries and water tubes. This power needs to go into a few different storage batteries to allow for multiple puzzles. Each one will scale in difficulty, and the series will start with the most basic circuit to complete (battery, two wires and the object to light up). Some further mechanics can be switches, resistors, multiple objects to light up, objects to rotate, and even some real examples instead of the oversized wires.

### **Other Details**

The easter egg in the room is a cup of cold coffee that is hidden on a table in the room. Once it's activated, a voice will tell them that if they scream at the coffee for just over eight years, the coffee will be nice and hot. The sound energy would be converted to thermal energy. The announcement would then say "Someone just discovered that yelling at coffee might actually be useful! ...Maybe."

Bear in mind that this has to have fourteen students all working at once. There may need to be multiple of the same example so that all of the students have something that they can experiment with. There are more types of energy than what is listed above and more examples can be made from them.

### ***Bunker / Future Room***

#### **The Experience**

Students enter the future room through an elevator in Mission Control or Power and Energy. This elevator takes them down to the lowest part of the lunar base, the safety bunker. This section of the lunar base is also equipped with a CAVE 3D projection chamber (VisionaiR 3D). In this room the students can experience 3D projections and interact with programs made available. The students have about five different touch screens that they interact with that can change the projections on the wall. Some projections will take over the entire room to show the kids a 3D movie experience. Other projections are

worlds which are more interactive. Each experience should be fairly short so there are plenty of different projections and movies to experience.

**Architectural Considerations**

The future room is a large square box with projections on all four walls and the floor. There are free open source editors that allow for custom movies to be created. The challenge in this room is that it needs to be able to handle fourteen students, a presenter and a chaperone. This means there needs to not only be enough room for everyone, but also enough to look at from all angles.

**Other Details**

Potential 3D programs:

1. Solar sail to Mars	2. Explore moons of Mars, Jupiter, or Saturn
3. Launch rocket fuel from lunar sling to Earth	4. Explore milky way and other galaxies
5. View time lapse of Voyager II's journey	6. Explore black holes and supernovae
7. Astrophysics Lab on the moon's far side	8. Small base on Mars' moon Phobos
9. Orbiting Fuel Depot	10. Orbiting Solar Power Array
11. Journey along a solar sail	12. Use a Space Elevator

The easter egg is accessed through a hidden touch screen located on one of the walls in the room.

Interesting space related phenomena are excellent candidates for this experience, and one example is showing the students the diamond planet. The announcement, "Good work students, you have discovered

the diamond planet! If we split up the entire worth of this planet (3 nonillion) equally, that's approximately \$4 sextillion dollars for each person currently on earth. That's a four followed by 21 zeros!" follows.

## Appendix

*Table A.1 - Suggested area for each Exhibit*

<b>Exhibit</b>	<b>Area (ft<sup>2</sup>)</b>
Little Theater	N/A
Observatory	900
Mission Control	8000
Water Elevator(s) Airlocks	600 (5x120)
Agricultural	2000
Biosphere	4400
Robot Room	4400
Material Processing	4400
Water Processing	4400
Power and Energy	4400
Bunker/Future Room	2000
Misc. ( <i>storage, janitorial, bathrooms, administrative, flex</i> )	1000
<b>Total</b>	<b>36,500</b>

**Note:** Little Theater exists on the main floor, so it does not factor in to the design space requirements

*Table A.2 - Events and timing*

<b>Event</b>	<b>Timing (minutes)</b>
Little Theatre	12
Observatory	3
Mission Control	30 + 5
Agricultural Unit	30 + 5
Biosphere	30 + 5
Robot Room	30 + 5
Lunch	30 + 5
Material Processing	30 + 5
Water Processing	30 + 5
Power and Energy	30 + 5
Bunker/Future Room	30 + 5
Group Discussion (Mission Control)	30
Total:	360

**Note:** 5 minutes of travel time is allotted while students flow from one exhibit to the next. This gives students just enough time to fully experience the water elevators (2-3).



*Table A.3 - Detailed Staffing Requirements*

Little Theater	<ul style="list-style-type: none"> <li>● Presenter (Same presenter for Mission Control)</li> </ul>
Base Entrance / Observatory	<ul style="list-style-type: none"> <li>● None</li> </ul>
Mission Control	<ul style="list-style-type: none"> <li>● 2-3 Cooks</li> <li>● Presenter (presenting from the real Moon to Earth via satellite video)</li> </ul>
Agricultural Unit	<ul style="list-style-type: none"> <li>● Guide</li> </ul>
Biosphere	<ul style="list-style-type: none"> <li>● 2 actors (<i>mock inhabitants of the base</i>)</li> </ul>
Robot Room	<ul style="list-style-type: none"> <li>● 2 Guides</li> </ul>
Materials Processing	<ul style="list-style-type: none"> <li>● Guide</li> <li>● Facilitator</li> </ul>
Water Processing	<ul style="list-style-type: none"> <li>● Guide</li> </ul>
Energy and Power	<ul style="list-style-type: none"> <li>● Guide</li> </ul>
Water Elevator	<ul style="list-style-type: none"> <li>● Automated Voice</li> </ul>
Future Room	<ul style="list-style-type: none"> <li>● Automated Voice</li> </ul>
Misc.	<ul style="list-style-type: none"> <li>● Curator</li> <li>● Janitors</li> <li>● Ticket Attendant</li> </ul>

	<ul style="list-style-type: none"><li>• Gift Shop Attendant</li></ul>
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**Note:** For the Worcester Auditorium, the little theater is on the main floor and the design space is in the basement. The basement cannot technically represent a multi-leveled moon base. Use of water elevators to transition from sub level to sub level allows us to emulate a technically feasible experience.

**Curator** - Runs all of the operations of the exhibit. Essentially a manager.

**Automated Voice** - Pre-recorded messages that instruct inform or teach the students.

**Facilitator** - Makes the exhibits function by operating something behind the scenes.

**Actors** - Pretends to be a part of the base, but doesn't necessarily assist the students with problems.

**Guide** -Assists the students in solving problems, but does not feed them answers.

**Presenter** - Teaches the students about certain concepts

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## Appendix B – AIAA Region I YPSE 2012 Conference, Abstract

### Proposal for an Interactive Lunar Base Exhibit

Since 1970 NASA's budget has dropped from 1.92 to 0.48 percent of the federal budget, and the Aerospace industry in the United States is facing a dire need for employees since 25% of current professionals will reach retirement age within 5 years. These two factors affect the future of the U.S. space program with relative uncertainty. The space race excitement is gone and young minds in our society require a fresh education initiative to reconnect and inspire them. What if the moon can be cast into a dynamic educational exhibit based on a circa 2069 lunar base that is technologically, economically, and politically feasible *today*? What if this exhibit, in parallel with a cumulative curriculum program for grades 5-10 in the Worcester Public Schools (WPS) system, provides hands on visual learning, review for MCAS (MA state exam) concepts, a unique yearly capstone experience, and an immersive environment akin to actually living and working on the moon? What if this exhibit also sought to inspire students, parents, educators, artists, enthusiasts, and professionals to work towards a common goal: usher in a new space age of discovery. An exciting exhibit that is designed with WPS Curriculum Benchmarks as the foundation can accomplish this.

One example exhibit could combine multiple benchmarks relating to the states of matter, the Periodic Table and compounds with the dry water found on the moon. A presenter starts by introducing a couple of elements and compounds in some of their states of matter. Two effective elements/compounds are nitrogen and carbon dioxide. For example, nitrogen is in the air as a gas, but in a liquid state, it can lower the temperature of objects so much so that they will shatter on light contact. Plants consume carbon dioxide to harness energy, but in a solid state, it becomes dry ice and will undergo sublimation (State change from solid to gas), which touches on benchmark **07.PS.09**. The

presenter can do examples with multiple elements from the periodic table, which touches upon **07.PS.04**. Furthermore, the Fahrenheit, Celsius and Kelvin scales will all be used throughout the exhibit, which covers benchmark **07.PS.08**. After this explanation, the presenter would go into H<sub>2</sub>O specifically, starting with water, then ice, then vapor. This leads into an explanation of how dry water works, where it can be found on the moon, and how we can turn it into useable water for a moon colony. It will have to be explained that dry water isn't another state of matter, but H<sub>2</sub>O in liquid form in a special compound. This exhibit could contain electrolysis systems (props), many elements/compounds in different states of matter and even some dry water samples.

Another example could be an interactive exhibit on robotics, where a group of visitors identify, repair, and implement robots for various purposes which covers benchmark **05.IS.01**. When visitors enter into the robotics area of the exhibit, they would be asked to take a robot base and imagine what sort of function it will perform, which is included in benchmark **07.TS.05** and **07.TS.07**. They can then customize the robots for mining operations, construction, transportation, or any other purpose the base may need. This can be accomplished with interchangeable parts, such as cameras, terrain compatible wheels, communication systems, and robotic arms and tools, which touches on benchmarks **08.TS.01** and **07.TS.03**. Visitors can then test their robots usefulness in a nearby testing area, performing various tasks like melting moon dust into a glass surface using lasers, or breaking through a crust layer with a drill. There will also be control consoles allowing visitors to interact with the robots as if they were actually on the moon, manipulating the cameras or rotating the robot to better use the tools they chose, which ties into benchmark **08.TS.06**. This could later be expanded to include students controlling actual robots working on the lunar base, using control consoles located in either the main control room of the lunar exhibit, or watching video feeds of the robots from their classroom. The robots could also be used

to visualize other exhibits that might not be feasible to interact with manually, including the above states of matter, with benchmark **08.TS.01**.

The potential for an exciting and interactive exhibit that inspires and educates students goes beyond the examples described here. This exhibit can change the idea of space discovery from an unrealistic thought to an achievable goal in the minds of our youth and future generations.

## Appendix C – Team Goddard Seminar, Dan Benoit

### Seminar Series – Dan Benoit

Wednesday October 10, 2012, 12:00pm – 1:00pm, SL-313

#### Key Talking Points

1. Team Goddard Architect Experience
2. What an Architect wants out of the Auditorium Space
3. What defines a “good” architectural program

1)

- High Tech Photos & Imagery, Idealized Space Travel/Discovery
- Understanding the needs required by the program itself
- Focus on what can be used, what the restraints are, and how to handle them
- Guide architects through technical boundaries and possibilities
- Remain flexible when giving limitations to architects, leave enough room to focus on important aspects of the program, or discard areas that are going to sink up a lot of time.

2)

- Enter the “Little Theatre” and get the sense that you are being brought to a Lunar Base
- Go down into the Exhibit through observation deck and into Mission Control, the centralized hub of exhibit
- Importance of a production/mining/assembly facility within exhibit
- Robot room, (remote Earth operation)

- Habitat Area
- Water Handling, Storage, and chemical processes
- “solar flare” bunker exhibit (Team Dempsey already postulated this in one of our earlier meetings!)
- Agricultural unit - “What can we grow on the moon?” (Tower Hill as a resource)

3)

- Specific exhibits based on curriculum
- How big is the space?
- How many students?
- How many groups?
- Importance of system of interrelated elements, i.g.
  - Program Elements -> Element Sizes -> Element Adjacencies -> Element Flow

### **Miscellaneous Notes**

Example of a staggered curriculum for a Robot Room (Grade 5-9)

- 5<sup>th</sup> – Expedition to the Equator (lava tubes, caves, etc.)
- 6<sup>th</sup> – Control Room -> Greenhouse (Tower hill?)
- 7<sup>th</sup> – Robotic Design -> Base Construction
- 8<sup>th</sup> – Chemistry -> Regolith mining and extraction, Hydrolysis
- 9<sup>th</sup> – Physics -> Helium 3, Fusion, etc.



Personally, Dan Benoit feels that the rest of the building would make an excellent Air and Space museum. This is not pertinent to the focus of our projects currently, but may play a role if we have time to start delving into the available purposes for the main floor and remainder of the auditorium.

## Appendix D – Team Goddard Seminar, Marc Andelman

### Seminar Series – Marc Andelman

#### Main Exhibits Covered

1. Agricultural Unit
  - a. Biosphere also
2. Water Processing

#### Agricultural Unit

Basically, there are 3 types of photosynthesis. C3, C4, and some other type I don't remember. I'll be in touch with Marc so I'll figure it out through him or independent research later this week.

C3 Photosynthesis is a more ancient process that requires higher concentrations of CO<sub>2</sub> in the atmosphere. This type of photosynthesis dominated when plants were much less prevalent on the Earth and CO<sub>2</sub> concentrations were much higher than they were historically. Still, there are plants that exist today that can thrive in a CO<sub>2</sub> rich environment using this type of photosynthesis. C3 Photosynthesis plants are also more sensitive to oxygen levels and this is a process known as photorespiration, and this is the main reason the agricultural unit will be toxic to humans. These C3 plants require higher CO<sub>2</sub> and less Oxygen.

Some examples of C3 photosynthesis are Potatoes and Yams. The ratio of CO<sub>2</sub>, Oxygen, and other gases in the air directly effects how fast these plants grow, and how big they grow as well.

C4 photosynthesis requires less CO<sub>2</sub> concentrations than C3 photosynthesis. Some examples include Cactus and Cat tails. Cactus use C4 metabolism to open their pores at night. Otherwise, they would risk losing water during the day. The cactus make CO<sub>2</sub> at night so they don't have all their stored water evaporate.

Marc also told us that you can see the difference on the plants leaf itself. Basically the pattern on the leaf will be indicative of C3 or C4 photosynthesis mechanisms.

Type of Photosynthesis	CO <sub>2</sub> Concentration (ppm)
C3	300-400
C4	180-280
3 <sup>rd</sup> unknown mechanism	???

The Agricultural Unit, I think, will be a CO<sub>2</sub> rich environment with less Oxygen, designed around helping C3 plants thrive. We can increase yield and size of starches and other vegetables, depending on the type of plants we can design around. An example of a game would be to modify oxygen and carbon dioxide levels in the agricultural unit to make the biggest yam or the fastest potato yield, i.e. some type of manipulative farm sim where the students are in direct control of the gas exchange system, also teaching them about gas cycles and how plants are quite diverse. The agricultural unit will look pretty much like a swamp, and students will have to wear safety suits or gas masks to enter. We can also try to incorporate animals that are native to this type of ecological system.

We can also use C4 photosynthesis plants around the base for aesthetic and functional purposes. Cat tails can be used for a variety of things, such as flour, sugar, and starch. You can even make COOKIES out

of them, surprisingly enough. I'm sure we'll be in touch with him again with more questions about these things. This is important for developing certain aspects of the Biosphere, such as common areas and living quarters, where plants will contribute to psychological relaxation. Some animals or insects that are native to an ecological system comprised of C4 plants can also be considered. The more natural the ecosystem is, the more robust and healthy it will be. (I have a lot of interesting TED talks on the current nature of agricultural farming vs. methods that are ACTUALLY sustainable, and the food is healthier and tastes better, or so the story goes.)

This information will allow us to do a bit more research and really flush out the agricultural exhibit, and incorporate other aspects of biology, chemistry, and plant/animal systems into the biosphere.

### **Water Processing**

Purification of the water requires a 3 step process, when you consider the waste water created by humans and the natural salinity present in the lunar soil. The lunar soil has natural salts in it so no matter where we get the water from we are going to have to desalinate it first, so it can be consumed by the humans in the base. Before that however the water needs to be filtered, and one of the ways we can accomplish that is the agricultural unit swampland. Swamps naturally filter and clean water. In addition to that, the waste water created by the lunar base inhabitants must also be taken care of.

Sewage Treatment – Waste water from humans is broken up. Need to do more research on this process, but basically the waste water is swirled around until it's broken up enough, and then it goes off to the agricultural unit swamp.

Agricultural Unit Swamp – The waste water from humans AND all liquid water obtained from the lunar soil is passed through the swamp. The swamp will naturally filter and clean the water. More research to

understand principles here is required, Marc is a knowledgeable source and can point us in certain directions.

Desalination – Once the water has been filtered through the swamp it needs to be desalinated, due to the high content of salts in lunar soil. There are several desalination methods available, but I'm not sure which one would be the best. Two contenders however, are Capacitive Deionization Activated Carbon and Ion Exchange Column. The important question on the moon is whether or not these processes can be used completely with local materials and how efficient they are at removing and then storing the excess salts.

A game system for Water Processing could incorporate any of these 3 sub-stages as part of a water purification system. For sewage treatment we could also get a lot more in depth describing how else human waste is used on the lunar base. A desalination game could easily be designed and we could even simulate the experience by first giving the students a glass of salt water, having them put it in a "machine" to process it, have them go through the science through a GUI, and then a clean glass of water (or some-what clean, depending on how well they do) comes out in response to their performance with the game. They will be able to physically taste the water before/after and this, I feel, is a really immersive way to make them think they are purifying water on the moon!

## Appendix E –Curriculum Benchmarks, 5-8<sup>th</sup> Grade

### Grade 5 Requirements

#### *Scope and Sequence*

##### **First Quarter**

The Earth/Rotation and Revolution

Phase for the Moon

The Water Cycle

Erosion and Weathering

The Solar System

##### **Second Quarter**

Magnetic Energy (Magnetic Poles and Fields)

Understanding Sound Production and Qualities

Under Sound Transmission

Understanding Light Transmission

Demonstrate Reflection and Refraction

##### **Third Quarter**

Identify Materials Used in a Design Task by Qualities

(Hardness, Softness, Flexibility, Conductivity)

Compare and Contrast Simple and Complex Machines

Develop and Understanding of the Engineering Design Process

(Problem Identification, Problem Representation, Design Features, and prototyping)

Compare Natural and Mechanical Systems

#### **Fourth Quarter**

Stimulus and Response

Instinctive and Learned Behavior

Adaptation

Evolution as a Means of Survival

Food Chains and Food Webs

#### ***Education Benchmarks***

##### **Skills of Inquiry**

--**05.IS.01** Ask questions and make predictions that can be tested.

--**05.IS.02** Select and use appropriate tools and technology (e.g., calculations, computers, balances, scales, meter stick, graduated cylinders) in order to extend observations.

--**05.IS.03** Keep accurate records while conducting simple investigations or experiments

--05.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.

--05.IS.05 Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiments.

--05.IS.06 Record data and communicate findings to others using graphs, charts, maps, models, models, and oral and written reports.

--05.IS.07 Use APA guidelines in writing science reports.

### **Earth/Space Science**

--05.ES.01 Recognize that the earth revolves around (orbits) the sun the sun in a year's time and that the earth rotates on its axis once approximately every 24 hours.

--05.ES.02 Make connections between the rotation of the earth and day/night, and the apparent movement of the sun, moon and stars across the sky.

--05.ES.03 Observe and discuss the changes in length and direction of shadows during the course of the day.

--05.ES.04 Describe the changes that occur in the observable shape of the moon over the course of a month.

--05.ES.05 Observe the sky every night for 30 days. Record every night the shape of the moon and its relative location across the sky.

--05.ES.06 Give examples of how the cycling of water, both in and out of the atmosphere, has an effect on the climate.



--05.E5.07 Give examples of how the surface of the earth changes due to slow processes such as erosion and weathering, and rapid processes such as landslides, volcanic eruptions, and earthquakes.

--05.E5.08 Recognize that earth is part of a system called the “solar system” that includes the sun (a start), planets, and many moons. The earth is the third planet from the sun in our solar system.

--05.E5.09 Compare and discuss erosion caused by equal amounts of water running down two slopes.

--05.E5.10 Compare proportional model of the solar system starting on the school playground and extending as far as possible. Demonstrate the size of objects (using a pea as the smallest planet and different size balls for the rest) and the distance between them.

### **Life Science**

--05.LS.01 Describe how organisms meet some of their needs in an environment by using behaviors (patterns of activities) in response to information (stimuli) received from the environment

--05.LS.02 Recognize that some animal behaviors are instinctive (e.g., turtles burying their eggs), and other are learned (e.g., humans building fires for warmth, chimpanzees learning how to use tools).

--05.LS.03 Discuss how newborn sea turtles find their way to the ocean.

--05.LS.04 Discuss how pets are trained to learn new tricks.

--05.LS.05 Discuss how migrating birds navigate.

--05.LS.06 Discuss the reasons and methods of animals migration (e.g., birds, reptiles, mammals).

--05.LS.07 Observe an earthworm placed on top of soil in a container that is exposed to light. Discuss how its ability to sense light helps it survive (by burrowing) and how its structure allows it to burrow through soil.

--05.LS.08 *Recognize that plant behaviors such as the way seedlings' stems grow towards light and their roots grow downward in response to gravity.*

--05.LS.09 Recognize that many plants and animals can survive harsh environments because of seasonal behaviors, e.g., in water, some trees shed their leaves, some animals hibernate or estivate, and other animals migrate.

--05.LS.10 Observe how a root system and stem of germination bean responds to changes in light by changing their direction of growth.

--05.LS.11 Give examples of how organisms can cause changes in their environment to ensure survival. Explain how some of these changes may affect the ecosystem.

--05.LS.12 *Discuss the importance of wetlands to human survival. Investigate how an invasive species changes an ecosystem*

--05.LS.13 Research local projects where humans are changing the environment to ensure a species' survival.

--05.LS.14 Describe how energy derived from the sun is used by plants to produce sugars (photosynthesis) and is transferred within a food chain from produces (plants) to consumers and decomposers)

--05.LS.15 Beginning with the sun as the source of energy and ending with decomposers, make a food chain. Create links that show the relationship of plants and animals in the chain. Show the direction of the flow of energy and discuss the results if various links in the chain are broken.

### **Physical Science**

--05.PS.01 Recognize magnets have poles that repel and attract each other.

--05.PS.02 Balance ring magnets on a pencil. Note: the shape of a ring magnet obscures the locations of its poles.

--05.PS.03 Identify and classify materials and objects that a magnet will attract and materials and objects that magnet will not attract.

--05.PS.04 Test a variety of materials with assorted magnets.

--05.PS.05 Recognize that sound is produced by vibrating objects and requires a medium through which to travel. Relate the rate of vibration to the pitch of the sound.

--05.PS.06 Use tuning forks to demonstrate the relationship between vibrations and sound.

--05.PS.07 Recognize that light travels in a straight line until it strikes a n object or travels from one medium to another, and that light can be reflected, refracted, and absorbed.

--05.PS.08 Use a flashlight, mirrors, and water to demonstrate reflection and refraction.

### **Technology/Engineering**

--05.TS.01 Identify materials used to accomplish a design task based on a specific property, e.g., weight, strength, hardness and flexibility.

--05.TS.02 Identify and explain the appropriate materials and tools (e.g., hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) to construct a given prototype safely.

--05.TS.03 *Identify and explain the difference between simple and complex machines (e.g., hand can opener that includes multiple gears, wheel, wedge great, and lever).*

--05.TS.04 Identify a problem that reflects the need for shelter, storage, or convenience.

--05.TS.05 Describe different ways in which a problem can be represented e.g., sketches, diagrams, graphic organizers, and lists.

--05.TS.06 Identify relevant design features (e.g., size shape, weight) for building a prototype of a solution to a given problem.

--05.TS.07 Compare natural systems with mechanical systems that are designed to serve similar purposes (e.g., a bird's wing as compared to an airplane's wing)

--05.TS.08 Apply the metric system in design projects and experiments.

## Grade 6 Requirements

### *Scope and Sequence*

#### **First Quarter**

Inquiry (Scientific Method)

Physical Measurement (Mass, Volume, and Density)

Conservation of Matter

Understanding measurement

#### **Second Quarter**

Atoms and Molecules

Atomic Models

Elements and Compounds

Models of Physical Features of the Earth

Describe the layers of the Earth

Explain Radiation Conduction and Convection

How the Sun's Energy is Distributed through the Earth's Environment

#### **Third Quarter**

Select Materials Appropriate for a Design Task

Select Tools Appropriate to the Task Assigned

Explain the Proper use of tools in prototype construction

Identify and explain the steps of the design process

Construct and evaluate a prototype and communicate a solution

Apply the metric System in the Design process

#### **Fourth Quarter**

Cell Structures

Cell Functions

Cellular Organization

Cell Differentiation

Body Systems

Body Organization

Compare Body Systems to Community Systems

#### ***Education Benchmarks***

##### **Skills of Inquiry**

--06.IS.01 *Formulate a testable hypothesis*

--06.IS.02 *Design and conduct an experiment specifying variable to be changes, controlled and measured.*

--06.IS.03 Select appropriate tools and technology (e.g., calculators, computers, thermometers, meter sticks, balances, graduated cylinders, and microscopes), and make quantitative observations.

--06.IS.04 Present and explain data and findings using multiple representations, including tables, graphs, mathematical and physical models, and demonstrations

--06.IS.05 Draw conclusions based on data or evidence presented in tables or graphs, and make inferences based on patterns or trends in the data.

--06.IS.06 Communicate procedures and results using appropriate science and technology terminology.

--06.IS.07 Offer explanation of procedures, and critique and revise them.

--06.IS.08 Use APA guidelines in writing science reports

--06.IS.09 Apply and understand measurements systems, e.g., English, metric and Kelvin.

### **Earth/Space Science**

--06.ES.01 Recognize, interpret and be able to create models of the earth's common physical features in various mapping representations, including contour maps

--06.ES.02 Choose a small area of unpaved, sloping ground in the school yard or a park. Create a scale contour map of the area. Include the true north and magnetic north.

--06.ES.03 *Describe the layers of the solid earth, including the lithosphere, the hot connecting mantle, and the dense metallic core.*

--06.ES.04 Use a Styrofoam ball and paint to construct a cross-section model of the earth.

--06.ES.05 *Differentiate among radiation, conduction, and convection, the three mechanisms by which heat is transferred through the earth's system.*

--06.E5.06 Investigate the movement of a drop of food coloring placed in water, with and without a heat source, and in different positions relative to a heat source.

--06.E5.07 Explain the relationship among the energy provided by the sun, the global patterns of atmospheric movement, and the temperature differences among water, land and atmosphere.

--06.E5.08 Note the relationship between global wind patterns and ocean current patterns.

--06.E5.09 Recognize that gravity is the force that pulls all things on and near the earth toward the center of the earth. (Gravity plays a major role in the formation of the planets, stars and solar system, and in determining their motions).

### **Life Science**

--06.LS.01 *Classify organisms that are currently recognized kingdoms according to characteristics that they share. Be familiar with organisms from each kingdom*

--06.LS.02 Describe diversity among living things.

--06.LS.03 Recognize that all organisms are composed of cells, and that many organisms are single celled(unicellular), e.g., bacteria, yeast. In these single-celled, organisms, one cell must carry out all the basic functions of life.

--06.LS.04 Observe, describe, record, and compare a variety of unicellular organisms found in aquatic ecosystems.

--06.LS.05 Compare and contrast plant and animal cells including major organelles (cell membrane, cell wall, nucleus, cytoplasm, chloroplast, mitochondria, vacuoles).



- 06.LS.06 Observe a range of plant and animal cells to identify the cell wall, cell membrane, chloroplasts, vacuoles, nucleus, and cytoplasm when present.
- 06.LS.07 Recognize that within cells, many of the basic functions of organisms (e.g., extracting energy from food and getting rid of waste) are carried out. The way in which cells function is similar in all living things.
- 06.LS.08 Describe the hierarchical organization of multi-cellular organism from cells to tissues to organ to systems to organisms.
- 06.LS.09 Describe different types of cells in a multi-cellular organism and how their characteristics relate to specialized functions (e.g., blood, nerve, skin).
- 06.LS.10 Identify the general functions of the major systems of the human body (digestion, respiration, reproduction, circulation, excretion, protection from disease, and movement, control and coordination) and describe ways that these systems interact with each other.
- 06.LS.12 Develop analogies of body systems working together to manufacture objects (e.g., car, bicycle, house).
- 06.LS.13 Record the account for areas of the skin more or less sensitive to touch.
- 06.LS.14 Measure, record, and interpret data during different activities that take place within the body systems and explain the importance of those activities (using external temperature strips).
- 06.LS.15 Describe the organization of the multi-cellular organisms from cells to tissues to organs to systems and how those system carry out life processes

--06.LS.16 Describe mechanical, electrical and chemical activities that take place within the body system and explain the importance of those activities.

--06.LS.17 Demonstrate and understanding of the systems of the human body and how they functions

### **Physical Science**

--06.PS.01 Differentiate between weight and mass, recognizing that weight is the amount of gravitational pull on an object.

--06.PS.02 Explain how to determine the weight of a dense object in air and in water.

--06.PS.03 Differentiate between volume and mass.

--06.PS.04 Define density.

--06.PS.05 Recognize that the measurement of volume and mass requires understanding of the sensitivity of measurement tools (e.g., rulers, graduated cylinders, balances) and knowledge and appropriate use of significant digits.

--06.PS.06 Calculate the volumes of the same objects by displacement of water, Use the metric system. Discuss the accuracy limits of the procedures and how they explain any differences between the calculated volumes and the measure volumes.

### **Technology/Engineering**

--06.TS.01 Given a design task, identify appropriate materials (e.g., wood, paper, plastic, aggregates, ceramics, metals, solvents, adhesives) based on specific properties and characteristics (e.g., weight, strength, hardness and flexibility).

--06.TS.02 Identify and explain appropriate measuring tools, hand tools, and power tools used to hold, lift, carry, fasten, and separate, and explain their safe and proper use.

--06.TS.03 Identify and explain the safe and proper use of measuring tools, hand tools, and machine (e.g., band saw, drill press, sanders, hammer, screwdriver, pliers, tape measure, screws nails and other mechanical fasteners) need to construct a prototype of an engineering design.

--06.TS.04 *Conduct tests for weight, strength, hardness and flexibility of various materials e.g., wood, paper, plastic, ceramics, metals.*

--06.TS.05 *Design and build a catapult that will toss a marshmallow the farthest.*

--06.TS.06 Use a variety of hand tools and machines to change materials in to new forms through forming, separating, and combining processes that cause internal change to occur.

--06.TS.07 Identify and explain the steps of the engineering design process, e.g., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

--06.TS.08 Apply the metric system in design projects and experiments.

## Grade 7 Requirements

### *Scope and Sequence*

#### **First Quarter**

Inquiry and the Scientific Method

Chemicals and the Periodic Table

Physics of Heat

#### **Second Quarter**

Physical and Chemical Change

Physics of Forces

Energy Flow in the Earth Systems

Physical Evidence for the Geologic Time Line

Plate Tectonics

Volcanism

Gravity

#### **Third Quarter**

Explain the Components of a Communications System

Demonstrate an Understanding of Electronic Devices Used in Solving Engineering Problems

Compare Different Types of Communications Technology

Identify and use international Icons and Symbols

Describe and Explain both custom and mass production

Manufacturing Systems

Explain Manufacturing Processes

Describe and Explain the parts of a Structure

Design and Construct a bridge

#### **Fourth Quarter**

Reproduction

Heredity and Genetics

Cell Division

Ecosystem Interaction

Biochemical Cycles

Organisms and Their Interactions with the Ecosystem

Energy Flow in the Ecosystem

Biodiversity

Adaptation

## *Education Benchmarks*

### **Inquiry Skills**

--07.IS.01 Formulate a testable hypothesis.

--07.IS.02 Design and conduct an experiment specifying variables to be changed, controlled and measured.

--07.IS.03 Select appropriate tools and technology (e.g., calculators, computers, thermometers, meter sticks, balances, graduated cylinders, and microscopes), and make quantitative observations.

--07.IS.04 Present and explain data and findings using multiple representations, including tables graphs, mathematical and physical models and demonstrations.

--07.IS.05 Draw conclusions based on data or evidence presented in table or graphs and make inferences based on patterns or trends in the data.

--07.IS.06 Communicate procedures and results using appropriate science and technology terminology.

--07.IS.07 Offer explanations of procedures, and critique and revise them.

--07.IS.08 Use APA guidelines in writing science reports.

--07.IS.09 *Apply and understand measurement systems, e.g., English, Metric and Kelvin.*

--07.IS.10 Use and understand scientific notation.

### **Earth/Space Science**

--07.E5.01 Describe how the movement of the earth's crustal plates causes both slow changes in the earth's surface (formation of mountains and oceans) and rapid ones (volcanic eruptions and earthquakes).

--07.E5.02 Use the Pangaea map to understand plate movement.

--07.E5.03 Research and map the location of volcanic or earthquake activity. Relate these locations to the locations of the earth's tectonic plates.

--07.E5.04 *Describe and give examples of ways in which the earth's surface is built up and torn down by natural processes, including deposition of sediments, rock formation, erosion, and weathering.*

--07.E5.05 Observe signs of erosion and weathering in local habitats and not seasonal changes.

--07.E5.06 Visit local sights following storm events and observe changes.

--07.E5.07 Make a timetable showing index fossils. Discuss which of these fossils are actually found in New England. Discuss why some may be missing from local rocks.

--07.E5.08 Explain and give examples of how local evidence, such as fossils and surface features of glaciations, supports theories that the earth has evolved over geologic time.

--07.E5.09 Recognize that gravity is the force that pulls all things on and near the Earth towards the center of the Earth. (Gravity plays a major role in the formation of the planets, stars and solar system, and in determining their motion).

--07.E5.10 *Differentiate among radiation, conduction, and convection, the three mechanisms by which heat is transferred through the Earth's system.*

## Life Science

--07.LS.01 Compare sexual reproduction (offspring inherit half of their genes from each parent) with asexual reproduction (offspring is an identical copy of the parent's cell).

--07.LS.02 Demonstrate an understanding of cell division and reproduction including mitosis and meiosis.

--07.LS.03 Give examples of ways in which organisms interact and have different functions within an ecosystem that enables the ecosystem to survive.

--07.LS.04 Study several symbiotic relationships such as oxpecker<sup>[sic]</sup> (bird) with rhinoceros (mammal) and identify specific benefits received by one of both partners.

--07.LS.05 *Explain the roles and relationships among producers, consumers, and decomposers in the process of energy transfer in a food web.*

--07.LS.06 *Organize various pictures of producers, consumers, and decomposers according to the relationship among the species.*

--07.LS.07 Explain how dead plants and animals are broken down by other living organisms and how this process contributes to the system as a whole.

--07.LS.08 Observe decomposer organisms in a compost heap on the school grounds, a compost column in a plastic bottle, or a worm bin and use compost for starting seeds in the classroom or in a schoolyard garden.



--07.LS.09 Recognize that producers (plants that contain chlorophyll) use the energy from sunshine to make sugars from carbon dioxide and water through a process called photosynthesis, and explain that this food can be used immediately, stored for later use, or used by other organisms.

--07.LS.10 Test sugars and starch in plant leaves.

--07.LS.11 Identify ways in which ecosystems have changed throughout geological time in response to physical conditions, interactions among organisms, and the actions of humans and describe how changes may be catastrophes such as volcanic eruptions or ice storms.

--07.LS.12 Study changes in an area of the schoolyard or a local ecosystem over an extended period and compare observations to those made by students in previous years.

--07.LS.13 Relate how numerous species could not adapt to habitat destruction and over killing by humans, e.g., woolly mammoth, passenger pigeon, great auk.

### **Physical Science**

--07.PS.01 Differentiate between mixtures and substances.

--07.PS.02 *Identify common elements by symbols (e.g., O, N, H, Ca, C)*

--07.PS.03 Use chemical formulas to describe molecular composition.

--07.PS.04 Demonstrate knowledge of the organization of the Periodic Table of Elements and use it to find information about an element.

--07.PS.05 Explain hydronium and hydroxide ions and interpret and use the pH scale.

--07.PS.06 Describe how heat energy is related to molecular motion.

--07.PS.07 Define temperature in terms of kinetic energy of molecules.

--07.PS.08 Understand the difference between Fahrenheit, Celsius, and Kelvin scales.

--07.PS.09 Describe how transfer of heat energy can cause a change in the state of matter.

--07.PS.10 Differentiate between physical changes and chemical changes and give examples.

--07.PS.11 Use investigations to analyze physical and chemical changes in substances and draw conclusions from their results.

--07.PS.12 Demonstrate with molecular ball-and-stick models the physical change that converts liquid water into ice. Also demonstrate with molecular ball-and-stick models the chemical change that converts hydrogen peroxide into water and oxygen gas.

--07.PS.13 Recognize that there are more than 100 elements that combine in the multitude of ways to produce compound that make up all of the living and nonliving things that we encounter.

--07.PS.14 Demonstrate with atomic models (e.g., ball and stick) how atoms can combine in a large number of ways. Explain why the number of combinations is large but still limited. Use the models to demonstrate the conservation of mass in the chemical reactions being modeled.

--07.PS.15 Differentiate between an atom (the smallest unit of an element that maintains the characteristics of that element) and a molecule (the smallest unit of a compound that maintains the characteristics of a compound).

--07.PS.16 Use atomic models (or Lego Blocks, assigning various colors to various atoms) to build molecules of water, sodium chloride, carbon dioxide, ammonia, etc.

--07.PS.17 Give basic examples of elements and compounds.

--07.PS.18 Describe and explain stages of matter in terms of molecular motion.

--07.PS.19 Describe boiling and freezing points using Celsius, Kelvin and Fahrenheit scales.

--07.PS.20 Identify and describe the four stages of matter.

--07.PS.21 Recognize that changes in temperature may cause changes in state, and demonstrate an understanding of physical and chemical changes.

--07.PS.22 Explain the effect of heat on particle motion through a description of what happens to particles during a change in phase.

--07.PS.23 *Give examples of how heat moves in predictable ways, moving from warmer objects to cooler ones until they reach equilibrium.*

### **Technology/Engineering**

--07.TS.01 Identify and explain the components of communication system, (source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination).

--07.TS.02 *Identify and explain appropriate tools, machines and electronic devices (drawing tools, computer aided design and cameras) used to produce and/or reproduce design solutions (engineering drawings, prototypes, and reports).*

--07.TS.03 Identify and compare communication technologies and systems, e.g., audio, visual, printed, and mass communication.

--07.TS.04 Identify and explain how symbols and icons (international symbols and graphics) are used to communicate a message.

--07.TS.05 Describe and explain the manufacturing systems of custom and mass production. Explain and give examples of the impacts of interchangeable parts, components of mass-produced products, and the use of automation, e.g., robotics.

--07.TS.06 Describe a manufacturing organization (corporate structure, research and development, production, marketing, quality control, distribution).

--07.TS.07 Explain basic processes in manufacturing systems (cutting, shaping, assembling, joining, finishing, quality, control and safety).

--07.TS.08 Describe and explain parts of a structure, (foundation, flooring, decking, wall, roofing system).

--07.TS.09 Identify and describe three major types of bridges (arch beam, and suspension) and their appropriate uses (site, span, resources, and load).

--07.TS.10 Explain how the forces of tension, compression, torsion, bending, and shear affect the performance of bridges.

--07.TS.11 Describe and explain the effect of loads and structural shapes on bridges.

--07.TS.12 Design and construct a bridge following specific design criteria (size, materials used) and test the design for durability and structural stability.

## Grade 8 Requirements

### *Scope and Sequence*

#### **First Quarter**

Inquiry

Scientific Method/Engineering Process

Heat and Temperature

Potential and Kinetic Energy

Conservation of Energy

Energy Changing Forms

Relationships between force and motion

Graph distance and time problems

Explain how forces interact on an object

Problems of reaction and Inertia

#### **Second Quarter**

Earth and Space Science Gravity/Motion

Eclipses, Moon Phases, and Tides

The Sun, Planets and Moons related to Gravitational Forces

What causes the tides? (Tides go in, tides go out...can't explain that!)

Observable Stars with and without visual aids

What is paleontology?

Measure the affect of Gravity on a falling object

### **Third Quarter**

Develop an Understanding of Transportation Systems

Develop a Solution for Transportation Problems Using the Universal Systems Model

Describe three subsystems of a Vehicle Their – Current Design and Function

Discuss How Future Technological Developments will Impact Transportation

Design a Future Transportation Mode

Explain an Adaptive or Assistive Device

Explain a Bio-engineered Product

Explain Integrated Pest Management

Brainstorm and Evaluate Alternative ideas for an adaptive device

### **Fourth Quarter**

Life Science Ecosystems

Life Science Cycles and Process

Recognize that Evolution is responsible for the diversity of species

Compare the development of the earth with the diversity of life

Become familiar with Darwin's theory of Evolution

Recognize that genetic Information is found on genes in the cell

Be knowledgeable of the human genome project

Understand the connection between genetics and evolution

Explain how variation and adaptations affect survival

Draw connections between extinct and modern species

Develop conceptual understandings between extinction and the environment

### *Education Benchmarks*

Skills of Inquiry

--**08.IS.01** Formulate a testable hypothesis.

--**08.IS.02** Design and conduct an experiment specifying variables to be changed, controlled and measured.

--**08.IS.03** Select appropriate tools and technology (e.g., calculators, computers, thermometers, meter sticks, balanced, graduated cylinders, and microscopes), and make quantitative observations.

--**08.IS.04** Present and explain data and findings using multiple representations, including tables, graphs, mathematical and physical models, and demonstrations.

--08.IS.05 *Draw conclusions based on data or evidence presented in table or graphs, and make inferences based on patterns or trends in the data.*

--08.IS.06 Communicate procedures and results using appropriate science and technology terminology.

--08.IS.07 Offer explanations of procedures, and critique and revise them.

--08.IS.08 Use APA guidelines in writing science reports.

--08.IS.09 *Apply and understand measurement systems, e.g., English, Metric and Kelvin.*

--08.IS.10 Use and understand scientific notation.

Earth/Space Science

--08.ES.01 Describe lunar and solar eclipses, the observed moon phases, and tides, and relate them to the relative positions of the earth, moon and sun.

--08.ES.02 Using light objects such as balloons or basketballs, and heavy objects such as rocks, make models that show how heavy a 1 kilogram (kg) pumpkin would seem to you on the surface of the moon, Mars, Earth and Jupiter.

--08.ES.03 Compare and contrast properties and conditions of objects in the solar system (sun, planets and moon) to those on Earth (gravitational force, distance from the sun, velocity, movement temperature, and atmospheric conditions).

--08.ES.04 *Explain how the tilt of the earth and its revolution around the sun result in an uneven heating of the earth, which in turn causes the season.*



--08.E5.05 Use globes and a light source to explain why tides on two successive mornings are typically about 25 hours, rather than 24 apart.

--08.E5.06 Recognize that the universe contains many billions of galaxies and that each galaxy contains many billion stars.

--08.E5.07 *Count the number of stars that can be seen by the naked eye in a small group such as the Pleiades; repeat with low power binoculars; again with telescope or powerful binoculars; research the number of stars present and discuss the meaning of their answer.*

--08.E5.08 Observe the velocity at which objects of various mass drop from a common height. Use a chronometer to accurately measure time and plot the data as mass versus time necessary to reach the ground.

Life Science

--08.LS.01 Recognize that biological evolution accounts for the diversity of species developed through gradual processes over many generations.

--08.LS.02 Become familiar with Darwin's Theory of Natural Selection.

--08.LS.03 Demonstrate how fossils are evidence for evolution.

--08.LS.04 Develop an awareness of Paleontology.

--08.LS.05 Compare the development of Earth with the evolution and diversity of life.

--08.LS.06 Recognize that every organism requires a set of instructions that specifies its traits and that these instructions are stored in the organism's chromosomes. (Heredity is the passage of these instructions from one generation to another).

--08.LS.07 Explain how dead plants and animals are broken down by other living organisms and how this process contributes to the system as a whole.

--08.LS.08 Recognize that hereditary information is contained in genes located in the chromosomes of each cell (A human cell contains about 3,000[Might be 30,000? Original said 30,00] different genes on 23 different chromosomes).

--08.LS.09 Give examples of ways in which genetic variation and environmental factors are causes of evolution and the diversity of organisms.

--08.LS.10 Become aware of how genetics affect evolution and adaptation of life.

--08.LS.11 Demonstrate how genetics affect evolution and adaptation of life.

--08.LS.12 Recognize that evidence drawn from geology, fossils, and comparative anatomy provide the basis of the theory of evolution.

--08.LS.13 Discuss the possibilities that a pterodactyl, a flying ancient reptile, is an ancestor of modern birds, based on its structural characteristics.

--08.LS.14 *Relate the extinction of species to a mismatch of adaptation and the environment.*

#### Physical Science

--08.PS.01 Recognize that heat is a form of energy and that temperature change results from adding or taking away heat from a system.

--08.PS.02 Differentiate between potential and kinetic energy and identify situations where kinetic energy is transformed into potential energy and vice versa.

--08.PS.03 Interpret the Law of Conservation of Energy.

--08.PS.04 Understand that energy cannot be created or destroyed but exists in different, interchangeable forms such as light, heat, chemical, electrical, and mechanical.

--08.PS.05 Explain and give examples of how mass is conserved in a closed system.

--08.PS.06 Melt, dissolve, and precipitate various substances to observe examples of the conservation of mass.

--08.PS.07 Heat sugar in a crucible with an inverted funnel over it. Observe carbon residue and water vapor in the funnel as evidence of the breakdown of components. Continue heating the carbon residue to show that carbon residue does not decompose.

--08.PS.08 Explain and give examples of how the motion of an object can be described by its position, direction of motion and speed.

--08.PS.09 Explain the way forces that work in pairs affect motion through their magnitude and direction.

--08.PS.10 Graph and interpret distance vs. time graphs for constant speed and velocity.

--08.PS.11 Demonstrate and describe how forces interact on objects.

--08.PS.12 *Demonstrate an understanding of Newton's Law of Motion.*

--08.PS.13 Demonstrate that forces must be overcome to have movement.

--08.PS.14 Recognize how friction may be useful and a problem.

--08.PS.15 Explain how everything is affected by gravity.

--08.PS.16 Describes influences that affect objects at rest and in motion.

Technology/Engineering

--08.TS.01 Identify and compare examples of transportation systems and devices that operate on land, air, water, and space.

--08.TS.02 Given a transportation problem, explain a possible solution using the universal systems model.

--08.TS.03 Identify and describe three subsystems of a transportation vehicle or device, e.g. cars, boats, airplanes, rockets.

--08.TS.04 *Design a model vehicle (with a safety belt restraint system and crush zones to absorb impact) to carry a raw egg as a passenger.*

--08.TS.05 Conduct a group discussion of the major technologies in transportation and how they might affect future design of a transportation mode.

--08.TS.06 Draw a design of a future transportation mode (car, bus, train, plane) and present their design, including discussion of the subsystem used.

--08.TS.07 Explain examples of adaptive and assistive devices (prosthetic devices, wheelchairs, eyeglasses, grab bars, hearing aids, lifts, braces).

--08.TS.08 Describe and explain adaptive and assistive bio-engineered products, e.g., food, bio-fuels, irradiation, integrated pest management.

--08.TS.09 Brainstorm and evaluate alternative ideas for an adaptive device that will make life easier for a person with a disability, such as a device to pick up objects from the floor.



## Best Benchmarks

### *5th Grade*

--05.IS.01 Ask questions and make predictions that can be tested.

--05.IS.04 Conduct multiple trials to test a prediction. Compare the results of an investigation or experiment with the prediction.

--05.IS.05 Recognize simple patterns in data and use data to create a reasonable explanation for the results of an investigation or experiments.

--05.ES.01 Recognize that the earth revolves around (orbits) the sun the sun in a year's time and that the earth rotates on its axis once approximately every 24 hours.

--05.ES.02 Make connections between the rotation of the earth and day/night, and the apparent movement of the sun, moon and stars across the sky.

--05.ES.04 Describe the changes that occur in the observable shape of the moon over the course of a month.

--05.ES.05 Observe the sky every night for 30 days. Record every night the shape of the moon and its relative location across the sky.

--05.ES.08 Recognize that earth is part of a system called the "solar system" that includes the sun (a star), planets, and many moons. The earth is the third planet from the sun in our solar system.

--05.ES.10 Compare proportional model of the solar system starting on the school playground and extending as far as possible. Demonstrate the size of objects (using a pea as the smallest planet and different size balls for the rest) and the distance between them.

**--05.LS.14** Describe how energy derived from the sun is used by plants to produce sugars (photosynthesis) and is transferred within a food chain from producers (plants) to consumers and decomposers)

**--05.PS.01** Recognize magnets have poles that repel and attract each other.

**--05.PS.03** Identify and classify materials and objects that a magnet will attract and materials and objects that magnet will not attract.

**--05.PS.05** Recognize that sound is produced by vibrating objects and requires a medium through which to travel. Relate the rate of vibration to the pitch of the sound.

**--05.PS.07** Recognize that light travels in a straight line until it strikes a n object or travels from one medium to another, and that light can be reflected, refracted, and absorbed.

**--05.PS.08** Use a flashlight, mirrors, and water to demonstrate reflection and refraction.

**--05.TS.04** Identify a problem that reflects the need for shelter, storage, or convenience.

**--05.TS.05** Describe different ways in which a problem can be represented e.g., sketches, diagrams, graphic organizers, and lists.

**--05.TS.08** Apply the metric system in design projects and experiments.

### **6<sup>th</sup> Grade**

**--06.IS.03** Select appropriate tools and technology (e.g., calculators, computers, thermometers, meter sticks, balances, graduated cylinders, and microscopes), and make quantitative observations.

--06.IS.04 Present and explain data and findings using multiple representations, including tables, graphs, mathematical and physical models, and demonstrations

--06.ES.07 Explain the relationship among the energy provided by the sun, the global patterns of atmospheric movement, and the temperature differences among water, land and atmosphere.

--06.ES.09 *Recognize that gravity is the force that pulls all things on and near the earth toward the center of the earth. (Gravity plays a major role in the formation of the planets, stars and solar system, and in determining their motions).*

--06.PS.01 *Differentiate between weight and mass, recognizing that weight is the amount of gravitational pull on an object.*

--06.PS.02 Explain how to determine the weight of a dense object in air and in water.

--06.PS.03 Differentiate between volume and mass.

--06.PS.04 Define density.

### *7<sup>th</sup> Grade*

--07.ES.09 Recognize that gravity is the force that pulls all things on and near the Earth towards the center of the Earth. (Gravity plays a major role in the formation of the planets, stars and solar system, and in determining their motion).

--07.LS.09 Recognize that producers (plants that contain chlorophyll) use the energy from sunshine to make sugars from carbon dioxide and water through a process called photosynthesis, and explain that this food can be used immediately, stored for later use, or used by other organisms.



--07.LS.11 Identify ways in which ecosystems have changed throughout geological time in response to physical conditions, interactions among organisms, and the actions of humans and describe how changes may be catastrophes such as volcanic eruptions or ice storms.

--07.PS.04 Demonstrate knowledge of the organization of the Periodic Table of Elements and use it to find information about an element.

--07.PS.08 Understand the difference between Fahrenheit, Celsius, and Kelvin scales.

--07.PS.09 Describe how transfer of heat energy can cause a change in the state of matter.

--07.PS.12 Demonstrate with molecular ball-and-stick models the physical change that converts liquid water into ice. Also demonstrate with molecular ball-and-stick models the chemical change that converts hydrogen peroxide into water and oxygen gas.

--07.PS.15 Differentiate between an atom (the smallest unit of an element that maintains the characteristics of that element) and a molecule (the smallest unit of a compound that maintains the characteristics of a compound).

--07.TS.01 Identify and explain the components of communication system, (source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination).

--07.TS.03 Identify and compare communication technologies and systems, e.g., audio, visual, printed, and mass communication.

--07.TS.05 Describe and explain the manufacturing systems of custom and mass production. Explain and give examples of the impacts of interchangeable parts, components of mass-produced products, and the use of automation, e.g., robotics.

--07.TS.06 Describe a manufacturing organization (corporate structure, research and development, production, marketing, quality control, distribution).

--07.TS.07 Explain basic processes in manufacturing systems (cutting, shaping, assembling, joining, finishing, quality, control and safety).

--07.TS.08 Describe and explain parts of a structure, (foundation, flooring, decking, wall, roofing system).

### *8<sup>th</sup> Grade*

--08.ES.01 Describe lunar and solar eclipses, the observed moon phases, and tides, and relate them to the relative positions of the earth, moon and sun.

--08.ES.02 Using light objects such as balloons or basketballs, and heavy objects such as rocks, make models that show how heavy a 1 kilogram (kg) pumpkin would seem to you on the surface of the moon, Mars, Earth and Jupiter.

--08.ES.03 Compare and contrast properties and conditions of objects in the solar system (sun, planets and moon) to those on Earth (gravitational force, distance from the sun, velocity, movement temperature, and atmospheric conditions).

--08.ES.05 Use globes and a light source to explain why tides on two successive mornings are typically about 25 hours, rather than 24 apart.

--08.ES.06 *Recognize that the universe contains many billions of galaxies and that each galaxy contains many billion stars.*

--08.E5.08 Observe the velocity at which objects of various mass drop from a common height. Use a chronometer to accurately measure time and plot the data as mass versus time necessary to reach the ground.

--08.PS.15 Explain how everything is affect by gravity.

--08.PS.16 Describes influences that affect objects at rest and in motion.

--08.TS.01 Identify and compare examples of transportation systems and devices that operate on land, air, water, and space.

--08.TS.02 Given a transportation problem, explain a possible solution using the universal systems model.

--08.TS.03 Identify and describe three subsystems of a transportation vehicle or device, e.g. cars, boats, airplanes, rockets.

--08.TS.06 Draw a design of a future transportation mode (car, bus, train, plane) and present their design, including discussion of the subsystem used.

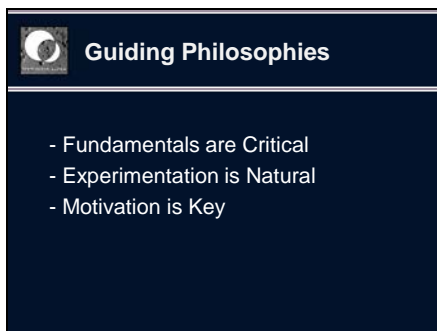
## Appendix F – Presentations

### High Stakes Presentation

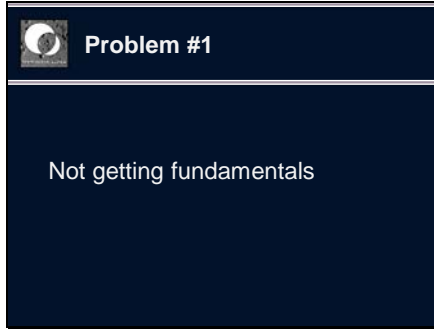
Slide 1



Slide 2



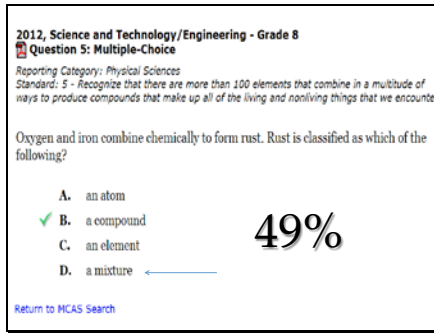
Slide 3



**Problem #1**

Not getting fundamentals

Slide 4



**2012, Science and Technology/Engineering - Grade 8**  
**Question 5: Multiple-Choice**  
Reporting Category: Physical Sciences  
Standard: 5 - Recognize that there are more than 100 elements that combine in a multitude of ways to produce compounds that make up all of the living and nonliving things that we encounter.

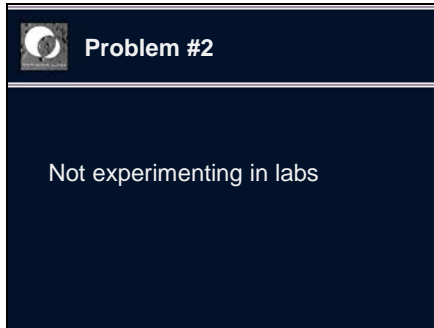
Oxygen and iron combine chemically to form rust. Rust is classified as which of the following?

- A. an atom
- ✓ B. a compound
- C. an element
- D. a mixture ←

49%

[Return to MCAS Search](#)

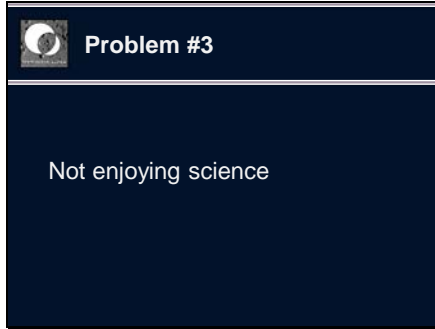
Slide 5



**Problem #2**

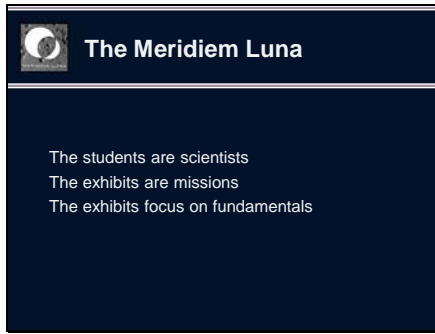
Not experimenting in labs

Slide 6



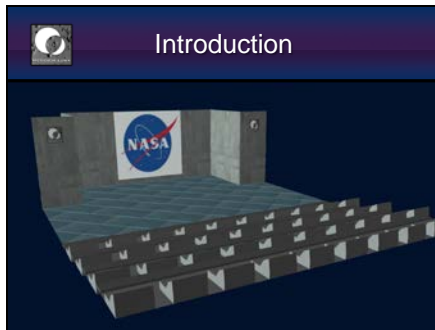
Slide 6 features a dark blue background with a white crescent moon icon in the top left corner. The text "Problem #3" is displayed in white at the top. Below a horizontal white line, the text "Not enjoying science" is centered in white.

Slide 7



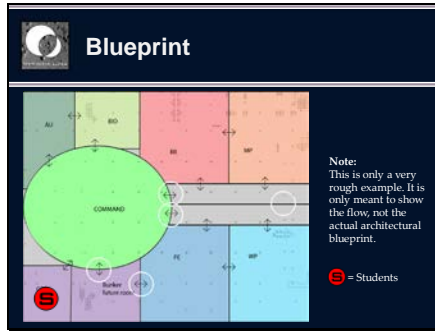
Slide 7 features a dark blue background with a white crescent moon icon in the top left corner. The text "The Meridiem Luna" is displayed in white at the top. Below a horizontal white line, three lines of text are listed in white: "The students are scientists", "The exhibits are missions", and "The exhibits focus on fundamentals".

Slide 8



Slide 8 features a dark blue background with a white crescent moon icon in the top left corner. The text "Introduction" is displayed in white at the top. Below a horizontal white line, a 3D rendering of a stage is shown. The stage has a blue checkered floor and a backdrop with the NASA logo. The stage is surrounded by a dark blue audience seating area.

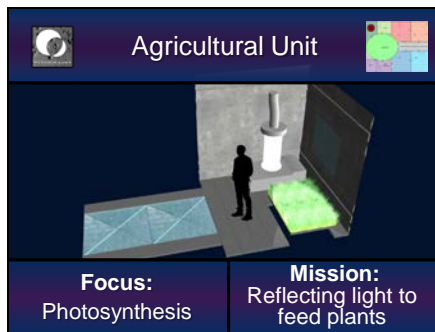
Slide 9



Slide 10



Slide 11



Slide 12



**Biosphere**

**Focus:**  
Forces and Gravity

**Mission:**  
Experiment with low gravity

Slide 13




**Biosphere**

**Focus:**  
Forces and Gravity

**Mission:**  
Experiment with low gravity

Slide 14



**Robot Room**

**Focus:**  
Engineering

**Mission:**  
Use robots to explore the moon



Slide 15


 **Materials Processing**




**Focus:**  
Compounds and Elements

**Mission:**  
Experiment with Regolith

Slide 16

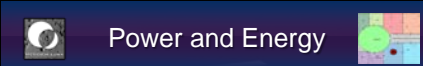
 **Water Processing**

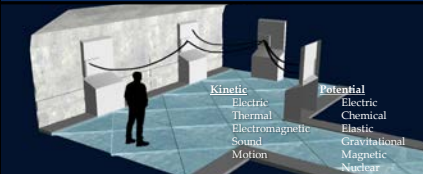


**Focus:**  
Properties of Water

**Mission:**  
Cleaning water for the base

Slide 17

 **Power and Energy**



**Focus:**  
Energy and Power

**Mission:**  
Power the rooms in the biosphere

**Kinetic:**  
Electric  
Thermal  
Electromagnetic  
Sound  
Motion

**Potential:**  
Electric  
Chemical  
Elastic  
Gravitational  
Magnetic  
Nuclear

Slide 18


 **Future Room** 



**Focus:**  
Problem Areas

**Mission:**  
Adventure through space

Slide 19

 **Scaling**

Start with fundamentals  
Build as far as we can take them

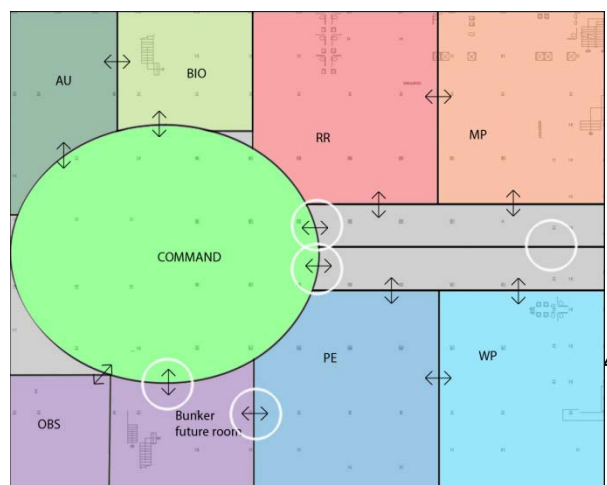
## High Stakes Handout



# THE MERIDIEM LUNA

### Exhibits:

- Mission Control (Command)
- Agricultural Unit (AU)
- Biosphere (BIO)



- Robot Room (RR)
- Materials Processing (MP)
- Water Processing (WP)
- Power and Energy (PE)
- Future Room (FR)

### FAQs

- I have a question about one of the models/blueprint.
  - ✚ Models and blueprints are not final. They are for demonstration and visualization purposes only.
- Is \_\_\_\_ going to be physical or virtual?
  - ✚ We hope that everything besides Mission Control and the Future Room will be physical. If it's not feasible then a virtual model will be used.
- An actual version of the \_\_\_\_\_ exhibit would actually be more like this...
  - ✚ Recreating some aspects of a circa 2069 lunar base will not be feasible. However, we do want to be as technically accurate as possible. Our goal is to create an environment that best teaches the basics kids need to learn, all while having an amazing field trip experience.
- How did you choose which education basics and fundamentals to focus on?
  - ✚ We looked at the 2007 Worcester Public Schools Science Technology and Engineering curriculum, and some of the texts currently being used in WPS. We also looked specifically at questions kids are struggling to answer on recent MCAS.
- Where would the connection between this and other foundations be?
  - ✚ The main area for supplemental material is Mission Control as the kids will be in front of screens the entire time; however, this can be done in other exhibits with relevant material.

- The way you described \_\_\_\_\_ was slightly off from the correct definition...
  - ✚ We don't want to be overbearingly technical with younger students. A major reason that students feel science is too hard is because of stringent technical definitions. If a concept is understood by students intuitively then a huge learning barrier has been removed. In the case of an egregious error, please don't hesitate to give us proper feedback.
- How much do you intend kids to learn by the end of the day?
  - ✚ If we have cleared up some of the basics they may have missed in the classroom, gotten them more interested in STEM and encouraged them to experiment (and learn!) on their own, we've done our jobs.

## YPSE 2012 Educators Presentation

Slide 1



Slide 2


**Exhibit Breakdown**

Lunar Surface (LS)	Base Entrance	Observatory and elevators into base	Flow	
Sublevel 1 (BL1)	<b>Mission Control</b>	Central communications and control	↓	
	<b>Agricultural Unit</b>	Food, gas exchange systems, materials		
	<b>Biosphere</b>	Living quarters, infirmary, recreation/housing		
Sublevel 2 (BL2)	<b>Robot Room</b>	Robotic construction, repair, and testing		
	<b>Materials Processing</b>	Regolith collection, processing, and storage		
Sublevel 3 (BL3)	<b>Water Processing</b>	Water collection, processing, and storage		
	<b>Power and Energy</b>	Harnessing Solar Energy and Helium 3		
Sublevel 4 (BL4)	<b>Bunker / Escape Room</b>	Emergency Bunker, 3D Projection Immersion		
LS-SL4	<b>Elevator</b>	Transit across sublevels of the base		↓

Slide 3

**Main Idea**

The students are the scientists



Slide 4

**Assistants**

Teach, but don't lead

Slide 5

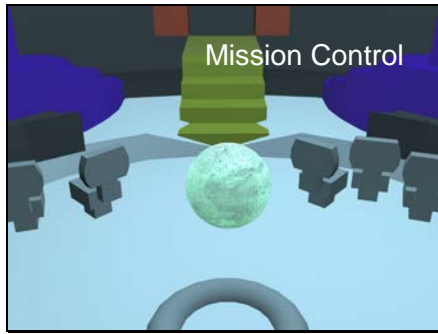


The Little Theater

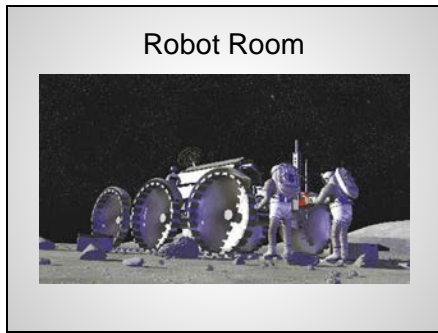
Slide 6



Slide 7




Slide 8



Slide 9

**Focus**  
Engineering & Technology



Configuring Robots to Complete Tasks

The image shows two students, a girl and a boy, standing in a classroom or workshop. They are both looking at a robot that is on a table in front of them. The boy is wearing a yellow shirt and the girl is wearing a white shirt. The robot is a small, white, rectangular device with some sensors and a camera lens.

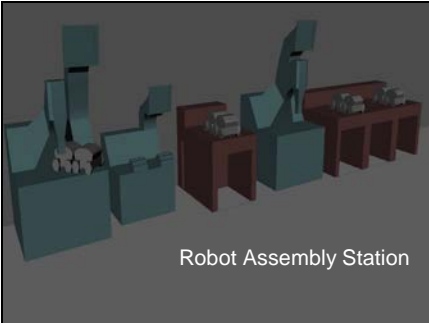
Slide 10

**Tasks Display Station**

Some potential tasks:

- a. Regolith Collection
- b. Surface Surveying
- c. Off-Site Robot Repair
- d. Off-Site Robot Construction
- e. Exploratory Drilling
- f. Expanding Infrastructures (Pow, Com, X-port)
- g. Expanding Base
- h. Handling Water
- i. Gas Exchange System Maintenance
- j. General Maintenance
- k. Agricultural Unit Maintenance

Slide 11

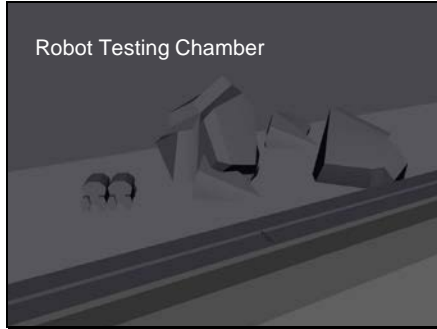


Robot Assembly Station

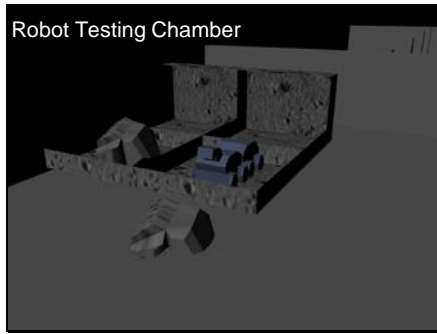
The image shows a 3D rendering of a robot assembly station. It consists of several workstations arranged in a row. Each workstation has a desk with a computer monitor and a chair. The desks are dark brown and the chairs are teal. The background is a dark grey floor and wall.



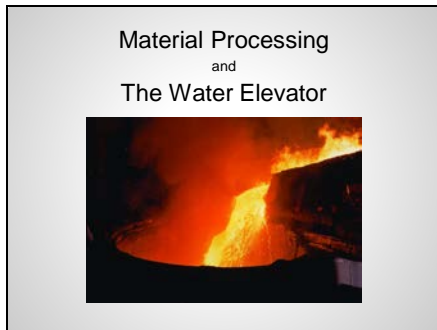
Slide 12



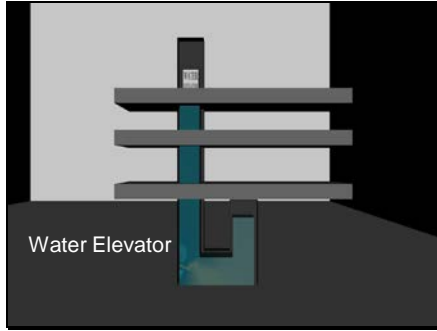
Slide 13



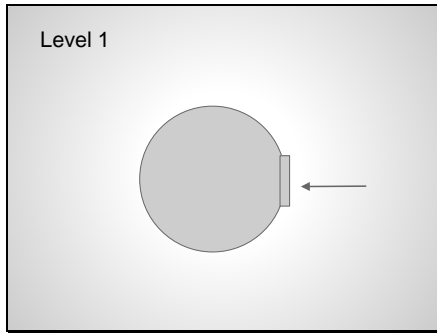
Slide 14



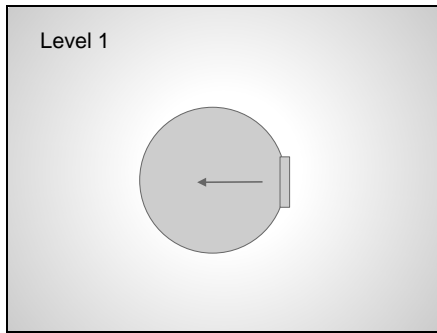
Slide 15



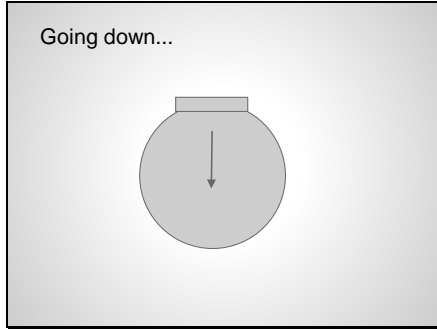
Slide 16



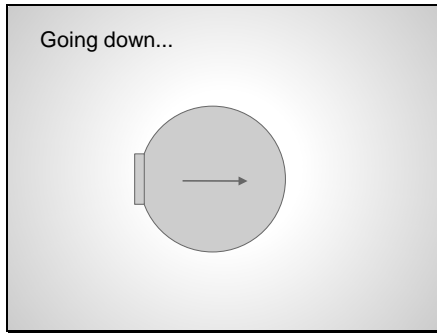
Slide 17



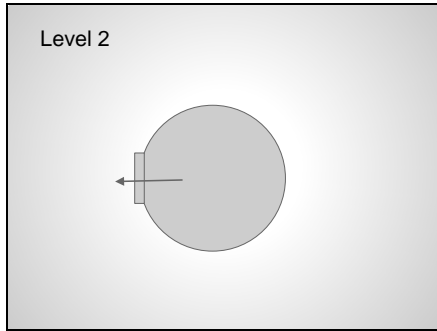
Slide 18



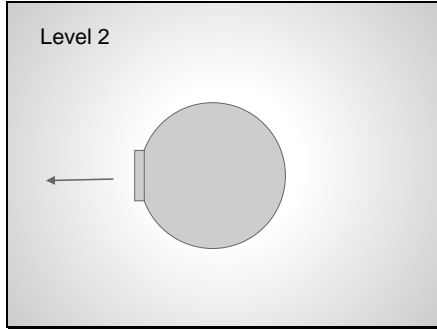
Slide 19



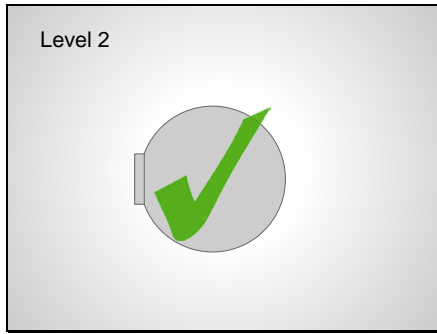
Slide 20



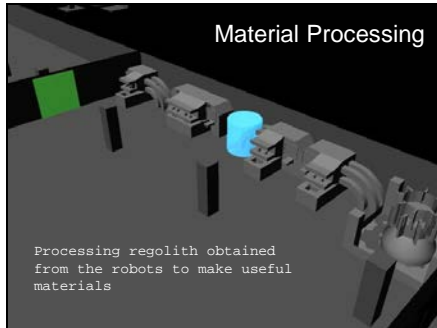
Slide 21



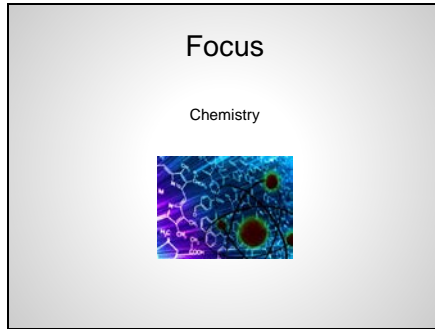
Slide 22



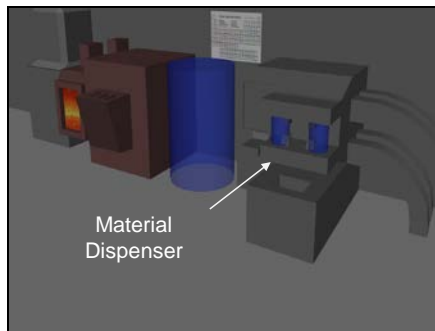
Slide 23



Slide 24



Slide 25



Slide 26


**Material Dispenser**

Gives the students regolith and dry water containers.

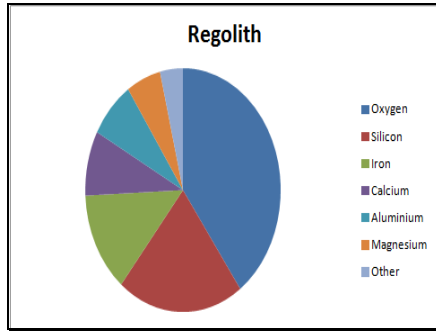
Regolith -

- a.  $\text{FeO}$  (Iron Oxide)
- b.  $\text{Fe}(\text{OH})_3$  (limerite)
- c.  $\text{SiO}_2$  (Silicon oxide)
- d.  $\text{Al}_2\text{O}_3$  (Aluminum oxide)
- e. Other:

$\text{H}_2\text{O}$  (Dry Water form)

A photograph of a rocky, greenish landscape, likely representing regolith or a simulated environment.

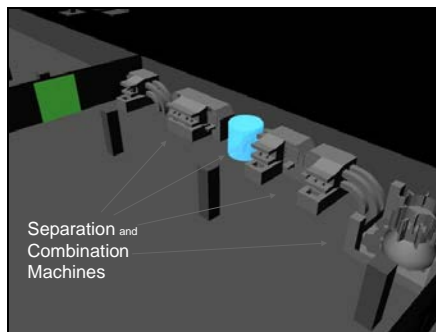
Slide 27



Slide 28



Slide 29



Slide 30

### Separation Machines

Dry Water	-->	Water Vapor
Water Vapor	-->	Liquid Water
Water vapor	-->	O and H Vapor (Rocket Fuel!)
(Element) Oxides	-->	(Element)

Slide 31

### Separation Machines

**Steam Chamber:**  
Evaporates the dry water into water vapor.

**Condenser:**  
Condenses the water vapor into liquid water.

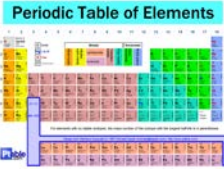
**Electrolysis:**  
Ionization, the water vapor into oxygen and hydrogen gas

**Melting Vat:**  
Separates the materials by melting them into liquid form so they separate by their densities.  
Can also combine materials with the right mixture.

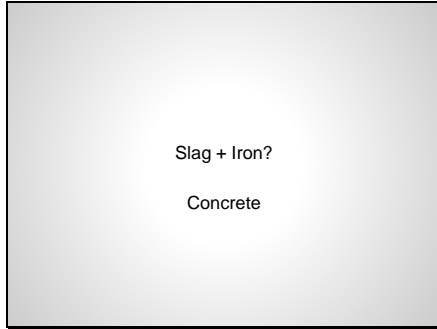
Slide 32

### Possible Materials

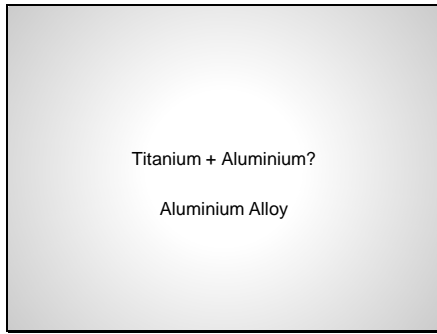
1. Water - H<sub>2</sub>O
2. Oxygen - O
3. Hydrogen - H
4. Silicon - Si
5. Potassium - K
6. Manganese - Mn
7. Chromium - Cr
8. Sodium - Na
9. Magnesium - Mg
10. Iron - Fe
11. Sulfur - S
12. Carbon - C
13. Nitrogen - N
14. Titanium - Ti
15. Aluminum - Al
16. Helium 3 - He-3
17. Helium 4 - He-4
18. Slag - Leftover Processing Material



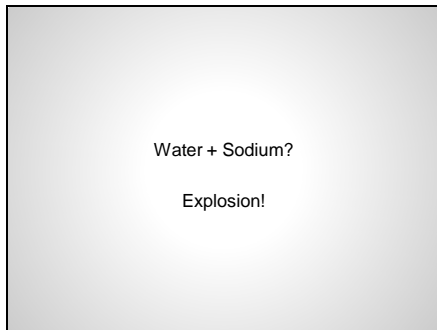
Slide 33



Slide 34

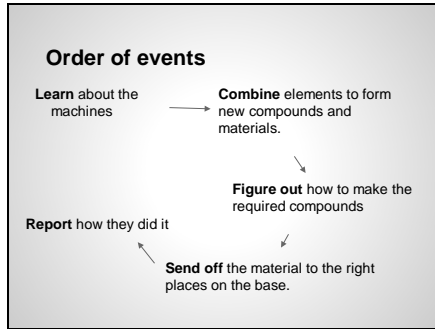


Slide 35





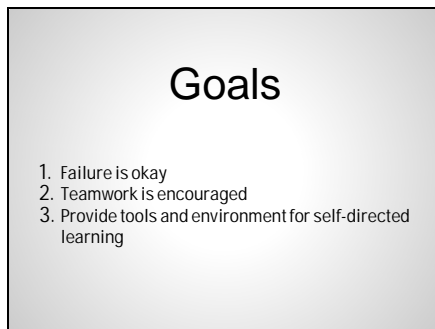
Slide 36



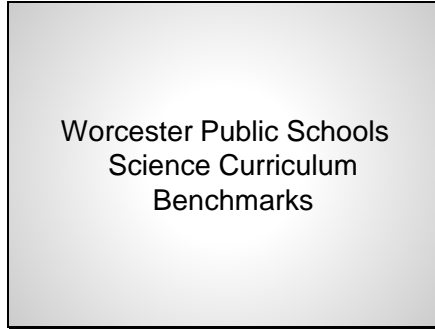
Slide 37



Slide 38



Slide 39



Slide 40

**Mission Control**

**5th grade**

- Earth/Moon Phase Diagrams (05.ES.04-05)
- Local Materials + Usages (05.TE.01-02)
- Earth vs. Moon Atm, explain air as a fluid medium (05.PS.05)

**6th grade**

- Mass vs. Weight Earth/Moon Sys (06.PS.03-04)
- Lack of magneto and atm, how this impacts radiation shielding (06.ES.05)

**7th grade**

- Scientific notation and terms, English/SI units (07.IS.06, 09-10)
- Two-body Earth/Moon system, explain how tides form (07.ES.09)
- Communications System for the base (07.TE.01,03)

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**Robot Room**

**5th grade**

- Choosing the right tool for robotic task (05.IS.01-03)
- Light tower and reflecting mirrors in agricultural unit (05.PS.07-08)

**6th grade**

- Closed System Life Support (06.LS.10)
- Information terminals that explain what certain materials are used for, and why. (06.TE.01)

**7th grade**

- Construction of a comm relay (07.TS.01-03, 05)
- Mass Production of Integrated Robotics Systems (07.TS.05-06)

Slide 42

**Material Processing**

- Density (06.PS.04)
- Elements/Compounds (07.PS.13)
- The Periodic Table of Elements (07.PS.04)
- Balancing Equations
- Inquiry Skills
- Metric/Kelvin Scales (07.IS.09)

Slide 43

WPI Spiral Curriculum  
Capstone Experience

Slide 44

**Mission Control**

Introduces a problem related to the spiral curriculum.

**5th grade**

- Mission to collect, process, and experiment with materials available in the lunar regolith.

**6th grade**

- Mission to repair the closed loop biosphere if it becomes contaminated or disconnected.

**7th grade**

- Mission to expand lunar communications systems to a new facility on the lunar surface.

Slide 45

**Robot Room**

**5th grade**

- Robotics mission to collect regolith for further processing in Material Processing

**6th grade**

- Robotics mission to investigate problems with the gas exchange system between the base and agricultural unit (i.e. CO2 leak)

**7th grade**

- Robotics mission to construct a communications relay system at the newly constructed facility.

Slide 46

**Material processing**

**5th grade**

- Perform various experiments with regolith collected previously

**6th grade**

- Determining which materials are required to repair an airlock or gas exchange feed system

**7th grade**

- Using the right materials to construct the comm relay system

Slide 47

**Questions?**

**Contact Information**

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