Interactive Qualifying Project

# The Educational Case for a Simulated Lunar Base

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# Contents

## Abstract

A renewed new space race between 3-5 nations seems likely in the 21st century, and the USA is no longer clearly the leader in space technology and science. Further, this subject is currently neglected in most secondary school science curricula. Hence, it is vital that public school students from grades 3-11 in the USA are taught about the solar system surrounding our planet. About 25% of the current aerospace corps of professionals is reaching retirement age in the next few years. This field will need to expand and become more interdisciplinary if the next set of challenges is to be met.

The moon, our closest neighbor, provides humanity with the first of many space faring challenges, and should be the focus of the proposed engineering and science program. If things move on NASA's preferred schedule with a first landing in 2020 and a scientific lab base camp completed by 2030, it is current college and high school students who will design the first self sufficient and self financing lunar base to be built about 2050. It is current elementary and middle school students who will build and man it.

One of the best ways to prepare the next generation is to build a mock lunar base, and have it in an exhibit in central New England, preferably in a substantial underutilized building with symbolic significance built in the era in which Robert Goddard was doing

his pioneering work on rockets in the Worcester area. He graduated from WPI in 1909, and then went to Clark University for graduate studies and then to join the faculty, so the critical 30 years of his career would be 1910-1940. The Worcester Auditorium, which was built between the two World Wars, is currently underutilized, has a massive basement and is symbolically appropriate. We propose that Worcester consider having the colleges and public schools in the city team up to build a mock lunar base circa 2050 exhibit at that site. They should also develop a spiral science curriculum for the public schools that is tied to the mock up such that the students can revisit it each year for 5- 8 years studying a different field or topic with utterly different activities each year.

The case for doing so, evidence of support for the idea by various key players and the potential long term economic advantages to the city are explored in some detail, as the story of our own construction of a table top model of a lunar base is described. Reactions by science teachers, members of the public interested in aerospace and Worcester children in grades 4, 6 and high school are all part of the story of how we explored the likely reception such a project would received from various audiences. The project was sponsored in part by the New England Chapter of the AIAA which funded an outside speaker on the subject that we brought from Huntsville, Alabama to speak to local high school, college and professional audiences.

## Introduction

A renewed new space race between 3-5 nations seems likely in the 21st century, and the USA has not been developing much useful space infrastructure over the last 30 years. Hence, NASA's plan to return to the Moon looks familiar, and has been classed Apollo on steroids. The Constellation project, NASA's plan to build a lunar base in the near future, is in political trouble, and its funding is currently under review. However, the idea of returning to the moon is a good one. The problem is that the public has never heard a good case for it and the space science community finds the Moon boring and wants to get to Mars ASAP.

NASA really wants to be told to get to Mars, not to build infrastructure for the development of the Moon, but NASA knows the moon is important.
It is a place where oxygen can be mined and thus rocket fuel can be produced that does not have to be lifted out of the Earth's gravity well. Hence, it has proposed to go to the moon to "practice" for Mars. Actually that does not make a lot of sense since the two environments are so different, so the critics are having an easy time attacking their strategy.

It is important for the public in general and especially the generation that would be asked to fund and execute the first efforts to develop the moon economically, to hear a serious case for the moon and to be comfortable thinking about the lunar environment and its economic possibilities. We estimate that this the group of students in 3rd to 11th grade at this time. However, if things moved on NASA's preferred schedule with a first landing in 2020 and a scientific lab base camp completed by 2030, current college

freshman might also be major players building the first self financing mining facility of the moon that we envision and want to depict in an exhibit in Worcester. It would be the effort of the next 25 years after NASA's proposed outpost is complete to build this self sustaining lunar base at the South Pole of the moon. Planning it might occupy those currently in college in their mid to late careers, but those who will build and man it are probably still in grade school and middle school,

One of the best ways to prepare the next generation is to build a mock lunar base, and have it in an exhibit in central New England, preferably in a substantial underutilized building with symbolic significance, such as the Worcester Auditorium. This was built during Robert Goddard's career between the two World Wars, and represented a moment of optimism about peaceful international cooperation represented by the League of Nations. Hence, it is a suitable place for visionaries and dreamers to plan the peaceful and cooperative development of space, amidst a background of international competition, starting with the moon. The challenge is as much institutional and political as technical, hence we propose to name it the Goddard-Kennedy lunar base exhibit acknowledging two of the pioneers who were ahead of their times and paved the way to this moment.

A simulated lunar base, in central New England, wherever it was put, would serve as an educational resource to students in the Worcester schools, and potentially to students throughout the New England region. The students can visit it to deepen their knowledge in Science, Engineering, Biology, Agriculture, and the entire spectrum of subjects taught in the school systems by applying what they know to the problems of living or working (in person or robotically) on the moon.

Worcester's central location in New England makes it ideal to host such a project, and have the resource be accessible to students and tourists looking for a field or day trip from Boston, Providence, Hartford, Springfield, Manchester, Lowell or Lawrence. Given the Goddard legacy, and the presence of a space suit manufacturer in Worcester, a lunar think tank and exhibit could lead Worcester to become one of the first cities in New England focusing on how to be a significant part of the future space economy.

Worcester has already hosted one gathering of technical pioneers. During the late 19th century portion of industrial revolution, the tinkers, inventers and mechanics building textile machinery for use in textile factories of Lowell and Lawrence were concentrated here. Prior to the emergence of these textile cities it was the Blackstone valley south of Worcester that was the early19th century hotbed of activity in this field. The Blackstone canal was built to get these heavy machines out of Worcester and to these production centers. The objections of Boston interests to the heavy traffic going through the port of Providence led to the building of one of the first railroads from Boston to Worcester. By 1860 Worcester was a major New England rail center with lines going to Boston, Providence, New Haven and Springfield. Worcester inventors are responsible for several innovations including the first machine that could fold envelopes. Producing such items at a rail hub was obviously advantageous for such companies.

The emerging space industry may afford Worcester a chance to be a technical infrastructure pioneer at the forefront of something critical to our society once again. This emergence with a new field of endeavor would unfold over a generation, with its implications at least 50 years away, but Goddard's efforts required that long to develop into a space program at president Kennedy's initiative. In this case New England will

have to get serious soon to compete with California and Florida, places that also want to be centers of space activity and have NASA bases around which to organize and focus their efforts. By comparison, New England will have to develop its own center, encourage it's experts and innovators to look farther ahead than NASA, and not be limited by its goals and manned space oriented mindset. It will also have to harness its advantage in quality public schools and institutions of higher education into a coordinated effort in cooperation with local high tech industry to be competitive. The colleges building an exhibit designed to support a math, science and social studies curriculum for the public school would be a start in this direction.

The scope of this project changed over time as new goals and objectives were developed to gain a better understanding of what needs to be done in order for an initiative of this kind to succeed. The Luna1 team worked with several groups of students from a nearby Worcester Elementary School and High School to try out some of our prototype curriculum concepts. One large challenge of which we took a first bite into was to conceive of a Space themed "Spiral Curriculum" in the Science classrooms of schools and implement a model to support one illustrative unit. Through our work with the students and teachers, we were able to learn about different interests of students, how to engage and encourage them, and got a glimpse at what an "exhibit" that is a model might add to a standard curriculum unit. The value added seems to be substantial but the upfront investment is also considerable. It would have to be used 50-100 times a year in various ways to be justified.

## The New Space Race

The potential importance of a lunar base is greater than ever before, due to the economically based space race that is shaping up today. Like the Apollo-era space race, there is great competition between nations to accomplish a major feat. However, unlike the first space race, this endeavor has to be worthwhile economic investment. The race is not merely about making a political gesture of technological superiority. Building the first base is not enough, as it has to lead to something substantial afterwards. Hence, this is about creating a stable base that can be used as a staging area for deep space missions, pay for itself in a reasonable time and then be profitable. Ideally it should be profitable enough to support further development of the necessary infrastructure technology to develop near space and go to Mars.

There are many resources on the moon that can be used in space, but some have to have value on Earth to support a lively trade. A lunar colony must be able to pay for necessary imports from Earth of materials abundant there but rare on Luna. The trade must also cover the need to import tools necessary to develop the moon's natural resources. The base itself ( and later the colony) will need to be largely self sufficient in terms of food and life support, though there will probably be imported hydrogen to mix with locally mined oxygen to produce water and rocket fuel.

It is likely that the trade items going to Earth will be precious metals such as platinum and chromium and the truly exotic lunar resource, Helium-3. Liquid Oxygen (LOX), Iron, Aluminum and the like from the moon will be valuable in space, even in

Low Earth Orbit (LEO), but probably not worth bringing to Earth, at least until transport costs have dropped by an order of magnitude. However, they would be precious if delivered other places, such as a space station, mission assembly point or refueling depot in space.

Currently, NASA plans to return to the moon and have a fully functioning lunar base by 2030, but then wants to move on and build another scientific station on Mars. It does not plan to develop the Moon but hopes private enterprise will take over once it pioneers the necessary lunar habitat and resource extraction technology. Officially, they are practicing for Mars, as they consider that the main prize in the solar system. That is a questionable policy, as Mars is more scientifically interesting but not more economically interesting than the Moon.

If the goal is a base that more than pays for itself by 2050, and can serve as a springboard to further exploration and development, it would have to be a semi-permanent facility on the Moon. NASA policy is not couched in terms of long run strategic advantage, but just trying to do everything first. That is not a cost effective policy stance, as it is thinking fame, glory and a place in the history books, rather than return on investment. There is also the question of how you want to be remembered? England was not the first nation to reach North America, but it was the country to develop and control this region (and shape the independent nation to follow) from initial colonies in Virginia and Massachusetts. The Dutch, French, Spanish and maybe Icelandic and Chinese expeditions that preceded them are not considered all that important in retrospect.

The lunar base that we envision would utilize the resource rich lunar dust, called regolith, which contains the main resources of interest, not to practice for Mars, but to create the foundation for a lunar colony and an Earth- moon trade system. It would be silly to practice oxygen extraction from regolith for a Mars base since on Mars there is a CO2 rich atmosphere from which to more easily extract oxygen. There is also ample water from which to derive life support and rocket fuel so the elaborate measures that will be taken on the Moon to obtain, make and conserve water would not be worthwhile on Mars. Carbon and Hydrogen are very rare on the Moon, and precious there, unlike Mars. Aircraft and windmills could be used on Mars but not the moon. Hence, a whole different infrastructure technology would be appropriate. Mars is more Earthlike, but has nothing the Earth needs or might want even at great cost. The Moon is very different and hence might have something truly precious to trade to Earth. It is also a staging area with a much shallower gravity well than the Earth as gravity is $1/6^{th}$ as great.

A WPI student named Joseph Paolilli wrote a paper entitled "Mining the Moon for Tomorrow's Energy". Joe points out many of the challenges, as well as the pay-offs of the kind of base we envision for 2050. Paolilli is not hostile to a Mars expedition. On the contrary, he would like to be part of one, but thinking pragmatically he calls for a self financing space program-and that means developing at least one self sufficient mining camp base on the Moon first. Then he is open to a national policy of space exploration to Mars in the name of science and the colonizing of space for its own sake as a cultural quest, rather than an entrepreneurial venture. Private and state enterprises looking at space as an arena for investment will be looking at the moon and then asteroids and space stations in near space. He presented this paper at the New England Air Museum during

Space Expo 2009 and again at the IASTS meeting in Rochester, New York about a month later.

Mining the Moon for Tomorrow's Energy
By Joe Paolilli (SD/Econ. Major) of WPI

The Earth will need an energy supply that will last for at least 500 years and can be obtained without disrupting the biosphere. On the Moon, such a supply exists: the Moon is the largest source of He-3 (a clean fusion fuel) in the inner solar system. It also possesses the raw materials needed for the construction of large solar-power arrays, which can then be used to beam power for the Earth. With or without the prospects of fusion power, the beginning of semi-permanent occupation of the Moon, combined with the end of the oil era, offers a remarkable chance to extend human civilization's energy resources beyond that which is available on the Earth alone.

This opportunity places the Moon in a position of economic significance that has not been reflected in recent space policy debate favoring the exploration of Mars. Although Mars has been the recent focus of attention, and with good reason as there is much important science to be done on Mars and its climate offers better prospects for human settlement, there is little besides information that the Earth needs from Mars. In brief, an economic case can be made for developing the Moon, but not Mars, and it puts the Moon back in the center of the space policy debate. We need a space program that can pay for itself, though the payback time may be too long (decades) to interest a traditional venture capitalist.

The economic case is simply the prospect that selling back to our planet the energy obtained by gas mining facilities on the moon will provide money to further sustain the lunar settlement, eventually payback the initial costs, and support the development of space exploration. This presentation covers the self-financing scenario; exploring the forces that would drive the development of a moon base into a fully functioning community; expanding on the lunar energy promise; and displaying the future lunar settlement as an economically self-sustaining entity. It also covers the nature of the fall back plan that would cover potential losses if nuclear fusion reactor technology is not mastered by the human race in this century.

During the 1960s, the U.S. was in competition, during the cold-war, with the former Soviet Union to be the first in outer space. The U.S. didn't make it to space (LEO) first with a radio satellite, dog or human passenger, but it did land on the moon first. The Soviets responded by building a series of space stations culminating in MIR, which lasted well past its design life of a decade. It was even visited by a few American astronauts before it failed and the International Space Station, a joint venture including the US and Russia, took its place.

So far, the American lunar missions have had no such continuing technological legacy, in part due to the unexpectedly high cost of constructing ISS in space rather than

sending up a smaller space station as a unit, which was the Soviet approach. However, to NASA that was the point of ISS, to learn how to do construction in LEO and then master how to maintain a continuously manned base. What science was done on the station was secondary. Indeed, building the space shuttle made no sense without a station to construct and then visit, but the shuttle was approved by the Nixon Administration well before the Space Station was approved by the Reagan Administration.

Nixon wanted to dismantle the expensive Kennedy era manned space program and focus on unmanned capabilities that had commercial potential. However, NASA sees its mission as building "step stones to the stars", taking mankind off of planet Earth, and so the station was not designed to pay for itself, or serve any particular mission or customer well. It was designed to serve various constituencies and create jobs, to hold together the Apollo team which wanted to get the go ahead to return to the moon and then push on to Mars. Reagan was more appreciative of grand symbolic gestures, but still tried to push NASA to view the space station as a place where commercial partners could test ideas and get access to lab space.

The shuttle program offered to the Nixon administration for the price of an unmanned space program was a fallback position to be built with off the shelf technology. However, it would provide several years of stable funding politically justified by the need to catching with and surpass the Russians and match the regular access the Russians had to LEO, create the ability of build a space station larger than theirs and surpass the Russian technology in being a reusable rather than an expendable launch vehicle.

The later space station would also be general purpose, designed to support many kinds of activity rather than to do any one thing well. For the same price we could have had 5-10 smaller special purpose space stations and man tended platforms in several LEO locations that might have paid for themselves. Indeed, for about what the price turned out to be, rather than the original budget, we could have had a lunar base, starting with the Apollo 20 mission. That was the original plan.

The ISS and Shuttle programs represent a kind of mission strategy and space construction logic that we can no longer afford as the US finally goes to the moon and builds a supply line and trade system for a permanent and self sustaining lunar base. Building space technology for its own sake is not making the case for investment in space facilities and infrastructure as cost effective in the long run.

The generation of engineers that were part of the Apollo program and the development of the shuttle to follow (during the period 1960-80) witnessed a massive buildup of organization, equipment and manpower followed by a sudden, sharp and severe cutback. Hence, they had to design the shuttle essentially out of off the shelf Apollo era technology rather than designing an efficient, elegant or robust shuttle craft. Indeed, they even had to stop building Saturn 5 rockets that could reach the moon after de eloping all the necessary facilities in Huntsville, Alabama and training the subcontractors needed to support the NASA rocket design team located there.

The Apollo generation could see that their field, up to 50,000 people directly and nearly twice as many indirectly supported by NASA, could not support more people since the program was not expanding or even maintaining itself. Further, the lack of R and D to take advantage of new and lighter weight components and materials probably would lead

to a technological gap in their near future. Worse, there came a time in the 1990's when NASA Administrator Dan Golden would be forced to lay off 50,000 aerospace workers, mostly contractors. Thus, the field would actually shrink at a time when it needed to be recruiting new talent to replace the aging Apollo era technologists then retiring. They are now in their 80's, and did not get to train young successors or pass on their dreams when they hit retirement age.

By contrast, during the 1970's and 80's Soviets were continuously launching and traveling to space stations on their reliable 2 man Soyuz system and supplying Mir with the unmanned Progress system. This was the period in which the USA had to stand down until it could design a whole new reusable spacecraft that could to access LEO with a crew of 7 and a substantial cargo.

However, in one last glorious flourish Apollo era NASA used its last two Saturn 5 Rockets (whose missions had been cancelled to save money for shuttle design) to launch its own small one shot Skylab space station and do a rendezvous in space with the Russians in the Apollo-Soyuz mission. Unfortunately, that meant that there was only one Saturn 5 left when SkyLab needed to be re-boosted to keep it in orbit. Since that was committed to the rendezvous with Soyuz, the American Skylab was allowed to fall out of space and burn up on reentry.

This was a distressing and humbling fall from grace for the American aerospace community that had pulled off Apollo and was not allowed to build on that success, or even look competent to the American public, (which could not understand why Skylab failed). The press had a field day. NASA had lost its only space station long before its design life was reached and there were no plans for another. Nor was there a heavy lift

rocket of the Saturn 5 class to launch another Skylab even if the US had wanted to. So there was not plan for a space station and no way to return to the moon. That raised a question about why we went to the moon in the first place, much less what we would get in return for that aerospace R and D investment? It would not be until 1985 that the significance of the Helium-3 in the Apollo lunar samples would be recognized and a modicum of discussion about a lunar base that would be commercial in nature would begin. NASA did not encourage this kind of speculation as it had no authorization to plan moon missions and now had the go ahead for a space station.

If NASA was to build a space station without a Saturn 5 class heavy lift vehicle, it would have to be constructed in space from smaller modular parts. In a way, the Russians were ahead in that field and pulling away as they had both a more powerful heavy lift rocket and experience with small space stations before building the larger MIR. They were clearly recovering from their failure to reach the moon and were getting the Americans to place their game at a disadvantage.

The US public was starting to ask who won the space race? Clearly the Soviets had logged more time in space and were getting more and more experienced. They also envisioned their space station as a spaceship just without the drive necessary to go anywhere. Still, they were keeping their people in space long enough to have gone well beyond the moon, sometimes long enough to have gotten to Mars, about 6 months. The Russians learned a lot about the impact of microgravity in space on the bones, muscles and fluid balance of humans, and the news was not good. The strongest Cosmonaut who swaggered to his launch vehicle would return to Earth after months in space barely able to stagger to a wheel chair to be taken away to a rehabilitation program. Full recovery

could take a year or more. Arrival on Mars in that condition was cause for concern even though the gravity was not as strong on Mars as on the Earth. Speculation began about the long term effects of lunar gravity, how long before one could not safely return to Earth?

Space stations were yielding useful information and the US wanted one, indeed von Braun had advocated building one before going to the moon, even though it was not absolutely necessary to the Apollo mission. His logic was different from that of the Russians. He saw a space station as infrastructure, not a practice space craft. Wernher von Braun had advocated building a space station as a place that would be a transshipment point en route to a key destination, such as a lunar base or colony. He had a much larger structure in mind than the Soviets and one that would have to be built in space. Thus, his vision is probably also the origin of NASA's concept of a shuttle craft that could take off like a rocket and land like a plane going to and from a space station that was a staging area. In effect, this meant that there would be a second vehicle designed for space that never landed on Earth or the moon but traveled between space stations in Earth orbit and lunar orbit. Thus, the NASA vision required mastering the art of construction of large structures in space while the Russian concept of why one would build a space station, really did not. It was an orbiting lab and proto interplanetary spacecraft.

The only missions interesting to the public that NASA was doing at the time it was building the shuttle involved space science, the Viking (landing on Mars) and Voyager (to the outer planets) missions. Meanwhile, the Soviet Union pulled off an unmanned landing on the moon and successfully returned lunar regolith samples to Earth,

partly matching the scientific yield of the Apollo missions. They also had evidence of Helium-3 in the regolith samples and knew what it meant, as they too were working on nuclear fusion technology so as to create hydrogen bombs. Theoretically, this was the perfect fuel for a fusion reactor modeled after the reaction on the Sun, harder to fuse than deuterium, but a much more powerful yield would result if you could figure out how to do it.

The dream of outer space exploration faded a bit as NASA focused on building a space truck with no place to go until the construction of a space station was approved. Sending a manned space craft with a crew of seven was a silly way to launch satellites but at the time it was the only system NASA had and it could afford to build only one. On its face, it was an expensive launch system of limited freight capacity for its size, costing about $10,000/ pound to LEO.

The existing NASA workhouse launcher, the Delta Expendable Launch Vehicle (ELV), was cheaper than that but was phased out in an effort to save money. NASA was also determined to make the case that a reusable space craft would be cheaper in the long run than expendable vehicles. In short, Delta could not be allowed to compete with the STS (Space Transportation System) shuttle for American payloads so as to keep its manifest full and justify the launch rate needed to make the system competitive with expendable launch vehicles (ELV's). The economics of the STS required a launch rate of about once a month with a fleet of four shuttle (or three trips per year for each shuttle) to make economic sense.

The bottleneck problem that threatened the economic logic of the STS program was the risk was the cost of turning around a shuttle to get it ready for another launch.

This was not a robust system, but rather bare bones in nature. In order to get the cost of development and construction down, anticipated maintenance costs were allowed to rise. Thus, the process of preparing a shuttle for another launch was labor intensive. The main concern was wear and tear on the vulnerable heat resistant exterior tiles of this system. The X-15 and other prior experimental rocket planes had actually had more sophisticated ways of resisting heat, including some active cooling systems. However, the shuttle was built on the cheap without using them. The cemented tiles cracked, fell off, required minute inspections and there were hundreds of tiles with unique configurations and characteristics to keep in stock. There were also known problems with the O rings holding together the field joints on the rockets, parts of which were also reusable.

The competition for the STS was all one shot expendable launchers made on an assembly line that did not have to be refitted or maintained, since they were simply replaced. This was the Russian to the approach to the Soyuz and Progress rockets and it simplified quality control and allowed one to seek economies of scale as one improved the design and assembly line over time. The STS fell behind schedule, costs per flight ballooned and after the Challenger accident in 1986 it was clear that each Shuttle would fly about once a year and ELV's would have to be kept in production as well. At this point it was clear that the STS program would never be cost competitive with ELV's.

The US Air Force had maintained production of the Atlas launch vehicle all along so as to be independent of the Shuttle, though Space Command also helped fund the shuttle program. In return it demanded that NASA build the shuttle's cargo bay larger than planned, to military payload specifications. The Air Force Space Command anticipated at some point having its own fleet of manned shuttles operating out of

Edwards Air Force base in California. This plan was scrapped after the Challenger accident in 1986.

For some reason Atlas was not providing cheaper access to space, though it was less complicated and proved to be more robust and reliable than the Shuttle, having been designed originally as an ICBM. So, with Delta out of production and Atlas not cost competitive, the private sector in the USA lost the commercial satellite launch market. ESA's Ariane rocket, which was marketed by the French company Arianespace, and launched out of French Guiana ultimately took 70% of the market. NASA's Shuttle could not compete and American's were no longer building the Delta series rockets that might have given the Ariane serious competition.

The Russian Energia and the Chinese Long March Rockets (the latter marketed by the Great Wall Corporation) would ultimately offer effective heavy lift competition to the Europeans and cut Ariane's commercial launch market share back below 50% by the year 2000. Though Boeing Corp. in the USA started building Delta rockets again after the Challenger disaster in 1986, the US Aerospace industry had fallen behind, had no government subsidies, and so lost its niche and was no longer a player in the international commercial launch market. The only customer that would rather pay more for domestic services than turn to foreign launch service providers was the US government.

So this is the situation the US finds itself in at the opening of the renewed space race to the Moon. About 25% of the talent pool in aerospace is reaching retirement age, by 2012 as there was little recruitment in the late 1980's and through the1990's. Most of the new recruits joining the field in that period were on defense contracts associated with the Reagan era "Star Wars" program. NASA was not building up its in-house talent pool

at the time, so the agency became increasingly dependent on expert employed by outside contractors. This is a radical departure from the Apollo era in which in house experts were monitoring the contractors and threatening to take projects in house to a NASA center if they were not satisfied.

The US also has no Saturn 5 class heavy lift rocket, and will have to design a new launcher or use several Delta V's to launch mission elements to LEO separately. One can then assemble crew and equipment there for a lunar mission. The NASA Constellation plan for the return to the Moon by 2020 involved two launches with a rendezvous in LEO. However, NASA also wanted to design two new "Ares" rockets for this mission, and send 2 missions each year for a decade to build the lunar base. It would be nice to use an upgraded version of the existing Delta for the freight lift part of the mission if there is insufficient funding to build something as powerful as the Saturn 5 was, but hopefully more efficient. It would also be nice to have a space station as an assembly point, but ISS is in the wrong orbit to support Moon or Mars missions, and clearly not what von Braun had in mind. It is where it is so that it can be supplied from Cape Kennedy in Florida or the Russian Baikonur Cosmodrome in Kazakhstan without going over China.

The logic of the US space program has been political rather than technical or economic for a generation and it shows in both the institution and the technology it has created. This has to change if the US is to build a space infrastructure and lunar base that can be paying for itself by 2050. This was the dream of the generation inspired by Apollo and recruited in the 1970's and early 1980's. Since they never got to realize that dream the question is how they can pass the baton to the incoming generation of scientists and engineers with as small a loss of organizational memory as possible? The

problem is that there is a missing generation in between them and the current generation that will be called on to return to the moon. Those few NASA technologists recruited in the late 80's and 90's never really got to think big or dream along these lines and most of their colleagues in aerospace were working on military contracts.

Ideally, these soon to be retiring post Apollo engineers and scientists should be interacting with students in middle school, high school and college today, and not just a few graduate students. Further they should meet in detailed mockups of what the old timers think could be and should be created. It is time to revive, and continue this dream, however, over the last 30 years science public school education has essentially dropped space science and astronomy. This seems to have been due to curriculum reforms designed by people convinced that space was passé and that the coming things were the revolutions in materials, communications and bio-technology. There are not even many classes devoted to Earth and Space Science for aero space visionaries to meet with before the university level.

So as a new space race with an economic logic and higher stakes than before is emerging, the US is really not the obvious leader. NASA as an organization has not been successful in international competition for income producing space activity or even a good business partner for public-private ventures. It is viewed as a source of contracts but the major players in the US space industry were not risking their own money on R and D designed to compete by bringing down the cost of access to space. It is only recently that new startups emerged to compete for the X prize that a spirit of innovation, entrepreneurial venture and competition has started to return to the space industry.

Our generation must produce those who can appreciate and understand this dream of developing space starting with the resources on the moon. It is we who must make sure that the US is a lead player in the new space race, rather than playing the role of the Dutch in the development of the new world in the 17th century. The Dutch settled Manhattan first but soon gave way to the serious players (in this case the British) who knew why they were there and were in it for the long haul.

It will soon become clear whether NASA is still serious, technically competent and capable of managing resources effectively as an economic investment. It will have to compete with 4 other space agencies that are considering lunar programs quite seriously, China, India, Russia, Europe and maybe Japan. Japan and India seem to want to work under the leadership of the USA if NASA is capable of setting a promising course and holding to it in a cost effective way.

While it is not yet a frenzy of activity, other nations have also begun to take an interest in being capable of space activity in LEO. Some, like Brazil, may develop aspirations to enter into a new emerging lunar trade system as well. By our count instead of two or three competitors with access to German technology developed in World War II (the United States, Britain and the USSR), the new space race broadly construed involves countries such as Russia, the Ukraine, India, Iran, North Korea, Brazil, Mexico, Canada, China, and Japan. Both Britain and France launched satellites independently and then Europe joined forces and created the ESA, which then spawned Arianespace.

ESA will remain a major power in the commercial space launch market and space science, but until now has not been interested in a manned space program separate from cooperation with NASA on projects like the space station. The British are agitating for

manned mission capability against Italian resistance while France and Germany seem ambivalent. A prior French proposal for a 2 man shuttle called Hermes (that an Ariane IV could lift) was scrapped due to the unwillingness of Italy to pay its share of development costs. Now, with the new more powerful Ariane V available, a less modest shuttle craft serving sizable space platforms could be considered. Meanwhile, ESA is purchasing Russian Soyuz rockets designed to carry a crew of two and setting up a launch pad for them in French Guiana. ESA will soon have a manned capability separate from that of NASA.

A small shuttle (reminiscent of Hermes) called HOPE was designed to ride the planned H-II launcher developed by the Japanese. The H-I mimicked the American Delta and required some American components. Export licenses for these were denied by the US for use in a commercial launch system, but allowed for scientific payload launches. Hence, the next generation H-II is sort of a next generation Delta with no components from the USA, though Boeing also built an upgraded Delta with heavier lift capabilities.

The development of the H II launch vehicle, now known as the H-II-A, was delayed as it ran into problems, both technical and financial. The redesigned H-IIB is much cheaper and only a bit less powerful, so HOPE as a 2-3 person shuttle may be back in the plans of JAXA, the Japanese space agency. For now, the HTV (that the H-IIB launches) is rated as a transfer vehicle for delivering freight to the ISS. The Japanese have long been interested in a manned capability, have built the materials lab portion of the international space station and now are working on how to access it with or without the US shuttle or the Russian Soyez.

There may be R and D alliances made among these competing space faring nations in the near future, for example Russia and India are talking about designing a craft that could carry more people than the US Shuttle and reach the moon for 2025. Such alliances tied to technology strategies make a United States presence among the partners all that much more important. It is evident that the US is losing its unchallenged place as the technology leader, and may actually fall behind if the next generation of planning goes ahead without our participation or development of a competing system.

As noted, the Japanese and Americans have shared technology. So have the Russians and Chinese, as the Chinese Shenzhou 3 man capsule is an upgraded and improved Russian Soyuz. The first two Chinese Taikonauts were trained near Moscow at Star City. China and Brazil have cooperated on satellite design. India recently sent a lunar mapping satellite to lunar orbit with assistance from NASA. Russia, USA, Japan and ESA have worked together on the ISS, but China was excluded. Europe is obviously looking at the proven Soyez as a model for its future manned system, but has also worked with the US and designed its own 2 man shuttle in the past. Things are still fluid.

Just when cooperation will break into open competition is not clear, but there will probably be a race for being the first to establish a lunar base at the south pole of the moon, which is where an estimated 80% of the water on the moon would be. China is expected to land on the Moon next, 2018-2020, before NASA can get back, but not to be ready to build a base by then. Russia and India could be landing by 2025. Projects of this type require about a decade of lead time, so the plans made in the next 5 years will be critical to who arrives when, but probably not the final outcome of who can build a base

that pays for itself and provides a basis for further extension into space. It is the students in the public schools who will determine that.

Looking at that international pool of students, the US is not doing very well in math and science education overall. Further, while about 1 in 3 Chinese high school students aspire to be an engineer, the situation in the USA is more complicated. In the heavily working class public schools of Worcester there is unusually high interest in engineering. According to Professor Wilkes of WPI, about 30% of the Worcester public School 8$^{th}$ graders (both boys and girls) say math or science is their favorite subject, but by 11$^{th}$ grade only 20% of the boys and 5% of the girls express interest in becoming engineers.

In fact, fewer than 10% will go on to actually major in engineering. Some couldn't qualify for admission, others could not pay for college and at many colleges and universities in the US (including Clark University, Holy Cross College, Assumption College and Worcester State College) there is no engineering major available. It is hard for the average Worcester Public School student to gain admission to WPI given the low average SAT scores of students in the local public schools. The advantages of having WPS students with technical aspirations meet WPI students and get coached on how to distinguish themselves in ways that would impress the admissions department could be quite substantial. Our proposal would provide one such meeting place.

While the NASA Constellation plan calls for starting construction on a permanent moon base in 2020, the Chinese have the ability to land in 2018. While there have been no formal announcements, the space museum in Beijing has a display depicting Taikonauts on a lunar rover. There is also a semi-secret plan for a manned mission to the

moon with an official code name. The Chinese are keeping their options open. They are serious about manned space and the ultimate goal is clear, so only the timing is at issue.

Treaties signed during the Cold War make it illegal for any nation to claim a heavenly body the way European imperialistic nations claimed the New World in the 15th and 16th centuries. However, there is also an understanding that one can appropriate and use local materials, so it does matter who sets up first in the prime sites of economic value. This could mean that China gains some advantages if it appropriates the South Pole for a base that is a proto-mining camp and staging ground for exploration on the ground. On a patriotic note, the United States won the lunar leg of the first space race. We have been the world leader in manned space since MIR was decommissioned and the Russians could not afford to replace it, so for the last 20 years. It would be truly sad in the USA did not get its act together and capitalize on that prior investment.

Now that many other nations are realizing the benefits that space has to offer, and investing heavily, we are losing our lead and in real danger of falling behind. It is now more important than ever that the United States puts more emphasis on space in the educational system and make a case to the public for lunar operations.

In summary, it is falling to the next generation to do what the last generation hoped to do 30 years ago. There is a new quieter, more economic and less political space race emerging and NASA has not proven to be a good business partner for American industry. The aerospace industry wants those government contracts, but does not trust NASA enough to co-invest in the way we have seen Europe and Japan approach space activity. The Chinese situation is nearly unique but Russia operated using the same communist state command economy model during its heyday of space technology

innovation. The USA should be prepared for serious competition in a great venture with high stakes resting on the outcome as the economic implications of developing the moon for its own sake, not as preparation for going to Mars become clear. Then there are additional advantages a lunar base would provide for those moving further out into space as well, not least of which is a way to pay for that mission as part of a profitable public-private space program.

## The Case for Construction of a Mock Lunar Base in Worcester

Sometimes the city of Worcester is overlooked because of its proximity to Boston. The capital of Massachusetts is home to the Boston Science Museum, the New England Aquarium, and the Museum of Fine Arts to name a few well known public exhibitions representing big ideas. This begs the question: Why not place the mock moon base in Boston? What makes Worcester an ideal location for such an exhibit? The answer rests within the history of Worcester. A history that welcomes industrialism, science, and most important to the base: space flight. Worcester, Massachusetts holds claim on one of the most profound legacies in scientific history. The legacy of Robert H. Goddard, the father of modern rocketry was a citizen of this city, and in fact, conducted much of his early research here.

Robert Goddard was born in Worcester on October 5, 1882. He spent his childhood looking at the stars, hoping to someday reach the moon or mars. He grew up in Worcester and, within the halls of its institutions of higher learning, would learn how to unlock the marvels of rocketry that time had kept secret. In 1908, Goddard graduated from Worcester Polytechnic Institute with a bachelor's degree in Physics. Two years later, he would receive a master's of art from Clark University and finally a philosophical doctorate from Clark in 1911. While he possessed a mind for science and engineering,

Goddard was a dreamer. In a speech to the 1904 South High School graduating class, he said:

> Often a science in its infancy, because it is unable to distinguish between path and barrier, falsely judges many things to be possible and others to be impossible; and an individual, setting out on his career, is often prone to consider that he knows what is open to him and what is closed. But, just as in the sciences we have learned that we are too ignorant to safely pronounce anything is necessarily within or beyond his grasp. Each must remember that no one can predict to what heights of wealth, fame, or usefulness he may rise until he has honestly endeavored, and he should derive courage from the fact that all sciences have been, at some time, in the same condition as he, and that it has often proved true that the dream of yesterday is the hope of today and the reality of tomorrow. (Goddard, preface)

Essentially what Goddard was telling this Worcester graduating class was that, the world is full of surprises and that what you work for today can be reality tomorrow. This connects with his love for space, of course, and is felt now as we prepare for a new space race.

Goddard was a professor of physics at WPI from 1908-1909. Working from 1914-1943 at Clark, Goddard was an instructor, assistant professor, professor of physics, and the director of the physical laboratories. During World War I (1917-1918), he developed the basis for the bazooka, which would ultimately lead him to the idea of using rockets for space flight. From 1915 to 1920, Goddard experimented with solid propellants for rockets and in 1921 switched to working with liquid propellants. His work with liquid fuel, which was funded by the Smithsonian Institution, took him through 1925 when he finally launched a rocket on his aunt's farm in Worcester.

His work on reaching space was clearly not finished by this point, nor would he ever get to see a man on the moon. In a correspondence with the author H.G. Wells, Goddard wrote:

> How many more years shall I be able to work on the problem. I do not know; I hope, as long as I live. There can be no thought of finishing, for "aiming at the stars", both literally and figuratively, is a problem to occupy generation, so that no matter how much progress one makes, there is always the thrill of just beginning. (Goddard, Preface)

Goddard knew he would not live to see a man in space, but he worked until the end, with the intention of passing this goal onto future generations, as there will always be ways of improving. We've sent men to the moon, but Goddard wanted more. As a citizen of this place, and a local hero, his legacy is Worcester's legacy. Worcester has inherited Goddard's legacy and should take his dreams seriously, making this city a prime location for an exhibit of this type, and of a high caliber.

Another credit to Worcester's rights for a simulated moon base is Worcester's industrial history. During the industrial revolution, the city flourished as a center of innovation. Ichabod Washburn's wire company, for example, both helped defend the trenches in Europe during World War I and was responsible for "barb wiring the West". The textile industries of Lowell and Lawrence would have collapsed without the inventive technological backing of the machinists of Worcester.

The city's central location has often helped serve as a meeting place for inventors as well as an ideal shipping depot for supplying New England with a myriad of goods. Its central location, coupled with being the second largest city in New England makes Worcester perfect for bringing people from all over the region to come pay a visit. The city of Worcester is also host to the Worcester College Consortium, a valuable resource of students, professors, and administration. The consortium could provide resources that would otherwise be unavailable. With the base open as an exhibit, it would be able to, at the very least, pay for itself, if not generate revenue. With the fact of being able to

"break even" in mind, it would be wise to direct attention to the cultural revenue that would be generated by such an exhibit. That aspect, the cultural one, would be a boost so large that it would not be able to be measured by conventional standards. Further, what we consider to be the ideal facility to house it is currently not in serious use.

The Worcester Auditorium was constructed as a memorial, commemorating the victory of World War I and remembering the sacrifice that many of Worcester's sons and daughters made during that war. At the moment it is not being used for anything except storing records. What once was a cultural center for the city is slowly growing more decrepit, a shell since only the exterior is being maintained. Hollow and abandoned it is a shadow of its former self. This building, however, has plenty of space in the basement to house a simulated lunar base while another more expensive attraction is prepared for the upper level. We understand that NASA is looking for places to give artifacts of the space age to for storage or display. The following are possible ideas for use of the auditorium, followed by the original project proposal and an abstract.

The ideas we have explained below for uses of the auditorium were often developed based on discussions with Edward Kiker, who came to speak in Worcester at the invitation of the AIAA New England Chapter, though we helped organize and justify his trip. He toured the Auditorium and since he has been involved in setting up other simulated space bases, declared that the cellar area by itself would be ample space and that the site was exceptional. He had never heard of an effort to do this kind of thing on such a grand scale and promised to help bring it about, to the best of his ability, if an institution in Worcester took on the project.

This is a significant offer, since in his talks to HS students at South High and at WPI it became clear that he prepared for much of his professional life to be the commander of the US Army corps of engineer's first Lunar Base. It seems that NASA is only authorized to build experimental and transitional facilities. A permanent or semi-permanent base, had it been built, would have been the job of the Army Engineers. His concept of what the base would do and look like proved to be compatible with our own. He agreed that it had to pay for itself and that it would probably mine LOX and Helium-3, as well as produce metals for local use and be the site of an agricultural unit.

The major problem with the auditorium as an exhibit site is that it will cost over $40 million to fully renovate the whole building. However, most of the expense would be in restoring the balconies, stage and a wide open area the size of a basket ball court or two. Part of the basement was already renovated and the rest that was not paneled and lit yet was even better as the site of a simulated underground base. He felt that a lot could be done for $10,000, and a facility that would be a national treasure and the best in the land could be done in this space for $100,000.

Ideally of course, one wants to see the main floor brought back and put to a compatible use, but the base did not require anything but a reception area near one door, access to the lower region from there and that the roof does not leak. The entry way is a beautiful marble room leading to stairs. It would do, but since there is a small auditorium on the other end with seating for about 100-200 people, that would be the best area to modify into a receiving and orientation area for an underground lunar base. This small auditorium area shares the stage with the main hall, and the stage is designed with an elevator that drops part of the stage into the lower levels. The elevator is large since it

was taken from a World War One Aircraft carrier. One could see what Kiker wanted to do if he had $100,000 to work with rather than $10,000. He wanted to renovate this end of the building.

As for the rest of the main floor of the building, one solution could be to find other businesses or organizations to help with the re-opening. They would be able to help with raising money for the renovation of the auditorium and the floor space could be rented out for many different types of activities ranging from political rallies to trade shows. However, to fit with the theme of the base and the purpose who which the building was created as a military memorial after World War one, the possibility of a military museum with an air and space theme is interesting.

There are lots of Civil War and some WW II museums, but few devoted to the story of World War One, and that was the first war in which airpower was a factor. Goddard was active in that post war period, working on the bazooka for the army, and it would be put to use in WW II. It is in that second war that the serious air and rocket technology starts to make its appearance. However, that is a familiar story of how the seeds of what would become the cold war space race are laid as both the Allies and Russians get their hands on German technology and technologists.

Ironically, the American interrogators of von Braun and his team find that in much of what is learned from them they are citing Robert Goddard, one of the 3 founders of the field with the German Hermann Oberth and the Russian Konstantin Tsiolkovsky. We were thinking that it would be dramatic to depict the air technology that Robert Goddard saw in the 1920's and 30's before World War II to help appreciate just how far

he was ahead of his time. One can thus honor him and acknowledge the WWI legacy and origins of the building.

The Worcester Auditorium was in its heyday about 100 years before the time we want to depict on the moon. It would be an interesting social studies/science field trip to see a World War I display honoring Goddard and his times, while putting the significance of his work in context. Then you go downstairs and flash ahead 100 years to 2040 or 2050 to get a science lessons looking into the future of the visionary space technology that Goddard co-pioneered.

Kiker is from "Rocket City USA", meaning Huntsville, Alabama, where von Braun and his team from Peenemunde did its work for the American Army and later NASA. That is a small city with an identity. This is where the team that ultimately developed the Saturn 5 moon rocket worked and the NASA Marshall base is still there. Kiker tells us that NASA is trying hard to find people who will take artifacts from the early days of space so that it will not have to bear the cost of storing them. He considers a museum with such a theme a real possibility and has already set up one such facility in Kansas. However, that exhibit looks to the past and he feels there is room for another such exhibit in this part of the country. We propose that this one to look back further than that period and then jump to the future. He thinks it would be easier to take the free gifts and build the future oriented special exhibit one floor down from 1960's space oriented displays he envisions on a restored first floor.

Either vision of what you do with the first floor would work. The question is which one is fundable to get started and will draw a crowd? The New England Air Museum in Windsor Locks, Conn. is asking the same question, and in planning its move

toward a space wing is thinking along Kiker's lines. It wants the Apollo era artifacts and already has WW I era air displays. Some cooperation moving toward coordinated space and air exhibits in which one advertises for the other (among people who have already visited its exhibit), might be possible. The two facilities would be drawing on the same region and both would want attention from the public schools.

In any case, if the auditorium is developed along these lines, the first floor has to pay for itself and a renovation. The simulated lunar base only has to pay for its set up and operations costs. The auditorium main floor could be a "museum-like" venue some of the time and still be "cleared" periodically to be set up for special events that did not draw on the first floor exhibits. One should still be able to bring in performers, trade shows, artists, cultural festivals etc. to help pay for building maintenance. The goal is to keep the space buffs, history buffs, and war veterans all happy, but not necessarily all at the same time. The core audience on an everyday basis would be students from grade three through college seniors.

In order to accommodate tour groups and school field trips, there should be a food court setup. We would like to see an area for artists/art students to sell pieces of space inspired works. NASA has a facility at Cornell University that specializes in artist's conception depictions of what the surface is like on other planets and moons in the solar system that are very dramatic. Works like this with an astronomy and space science motif would enhance the overall atmosphere and inspire local to create more such images. Furthermore, we would like to see a "Space-camp" program could be setup for young kids or grade 3-7 students. It could be a 6 hour program where younger children do a lot of activities and learn a lot about the moon and outer space in a fun filled atmosphere.

With these ideas in mind, a foundation is set for thinking about a large range of compatible uses of the Worcester Auditorium main floor space. One does not have to decide at this point whether in the end the lunar base will displace the World War I and interwar years museum concept to another building or whether the museum will grow and develop and crowd out the lunar base. Either one could move to another nearby building. Testing the waters with the educational science display is just the start of considering the possibilities.

## The Proposal to the City of Worcester

The following document has been prepared as the "brief" 5 page version of the case made this far suitable for distribution to city administrators, school officials, science teachers and even members of the AIAA, New England Chapter. We hope that they will cooperate on a proposal to fund the $100,000 version of the lunar base exhibit while doing local fund raising to start with something like the $10,000 version Edward Kiker suggested would be the minimum worth doing in such a fine space as the Worcester Auditorium basement.

**Proposal for a Simulated Lunar Base in Worcester**

**A Proposal to the City of Worcester, and especially its' Public Schools**

History has shown Worcester, Massachusetts to be an innovative city that has thrived at the forefront of technological change. During the Industrial Revolution,

Worcester was noted as the center of new inventions. The city's inventors supported the textile industry centered in Lowell and Lawrence and developed machines that fostered a number of other fields. Recently, the focus has been on being part of the bio-tech surge; however that started elsewhere, so Worcester is participating rather than leading in the field at the moment. Hence, Worcester's' leaders and citizens are, once again, looking for a way to return to their place as a leading center of innovation. Worcester's next opportunity to host a hotbed of pioneers may coincide with the reemergence of the space industry as a new and entrepreneurial field. This venture will be designed to develop the resources of near space into a self sustaining and profitable extension of Earth's economy into space.

This new age of exploration will start with the development of the moon if innovators here can figure out how to do this is a self-financing way. NASA plans to build a base there between 2020 and 2030, but they are not thinking about a self-financing enterprise. NASA is known to have a desire to privatize space (with the urging of the U.S. Congress), which creates a moment of opportunity. With new and old powers, like Russia, China, Japan, India, and the European Union all showing interest in the moon as the closest target in a resource race, this is likely to be, for the second time the occasion for a space race.

The large aerospace technological edge of the United States 30 years ago is fragile today – and the post Apollo generation of scientists and engineers is retiring now. Our proposal is designed to rekindle an interest in space on the part of young middle and high school students. We want to begin creating an interest in the future generation of scientists and engineers and mark Worcester as the place to go to study space.

In order to spark this interest as a cooperative international new age of discovery, we propose that a mock lunar base be built in a major underutilized building in Worcester, ideally the basement of the Worcester Auditorium. This building, is going to waste at the moment, and constructing an artificial moon base would show area students what it would be like to live or work on the moon. The mock lunar base could be combined with a spiraling science curriculum, delivered to the Worcester Public Schools (WPS), by teams based at nearby science oriented colleges working under WPS oversight. These units would be designed to give students both a theoretical and a practical view of the space, and particularly the lunar, environment.

A spiral curriculum returns to a topic year after year, but builds on the prior work, going into greater and greater depth. Month long units each year culminating in a field trip to the nearby lunar base is the level of attention we envision to this part of physical science and engineering design. Both science and design issues are covered by the MCAS assessments mandated by the Commonwealth of Massachusetts.

An Earth economy that has a heavy space component is a very large possibility in the not-so-distant future. The USA aspires to be one of the leading space faring nations. The population of the planet is increasing rapidly and reserves of natural resources are being drained increasingly rapidly. It makes sense that the next big move to increase the resource base is will involve activity in space and in the ocean's of Earth. The harder and more interesting question involves space, and particularly energy resources located on the moon. Worcester has a space legacy and is not a port city, but located inland. Wood's Hole on Cape Cod will probably be leading the region's push to more completely explore

the seas. Like Huntsville, Alabama Worcester should make pioneering in space part of its image and identity.

A curriculum that touches on and builds on that theme is a change that would prepare today's students for careers in fields that will be expanding over the next 20-30 years. An example of such a lesson plan would be to have seventh and eighth graders spend a month on the fundamentals of "moon science", much like the current general surveys of Earth science. Then perhaps in ninth grade, a month on power sources suited to use on the moon like solar and nuclear energy. In tenth grade the students could examine biological issues centered on agriculture and life support systems. The next year they could touch on robotics and transportation, and finally as seniors they would be ready to tackle mining, production and trading challenges, ie. the kind of technology that has economic implications.

Each month-long lesson would be capped with a visit to the moon base exhibit to see what the college students studying in Worcester and double majoring (or minoring) in space studies (along with a traditional major) are looking into and find promising. Assessing their proposals and critical evaluation of these possibilities can occur in the public schools especially by the seniors in HS who will soon be in college. Thus one set of visionaries can stimulate the next generation of dreamers as well as giving them some role models.

A science and technology curriculum of high caliber is one that would span different disciplines and involve hands on activities. For the subjects suggested, mostly physical science and some social studies units would be appropriate. What we would ask of the Worcester School Committee is to assemble an appropriate group of educators as a

curriculum review committee so that future teams of WPI, Clark and other college students can engage them in discussions about the possibility of curriculum development projects in conjugation with this undertaking.

It was an appropriate year to think about living and working in space to honor the local hero, Robert Goddard when we started this project in 2009-10. Goddard, a native of Worcester, graduated from Worcester Polytechnic Institute in 1908 with a Bachelor's of Science in Physics, one hundred and one years before. Thus, this is a suitable spinoff of the anniversary celebration. . After graduating he became a professor at Clark University. Goddard once wrote, in regards to his childhood, "As I looked towards the fields at the east, I imagined how wonderful it would be to make some device which had even the possibility of ascending to Mars."

The New England region needs a center of industry for the new space era and Goddard's Legacy makes Worcester the ideal spot to generate some space businesses in a local business incubator. The exhibit we propose would be part of a larger plan to start a local and rapidly growing enthusiasm for the emerging space industry. Worcester Auditorium is the ideal place for the proposed educational moon base as it is close to WPI, meaning that it can tap the resources of the only local institution with substantial numbers of engineering majors fairly easily, and it is in near the center of Worcester, making it easy to access for the secondary schools and the public.

Worcester needs to take better advantage of its assets as a "college town" and partner up its college and business leaders to plan its future. The New England Chapter of the American Institute of Astronautics and Aeronautics (AIAA) has reviewed an early draft of the educational lunar base proposal and is tentatively supportive of the idea. It

has invited us to present our vision of the idea at one of its meetings, and promised to hold the meeting in Worcester, though it normally meets in the Boston area.

This change in venue would be to facilitate attendance by interested science educators in this city. The AIAA chapter has also agreed sponsor other WPI project teams and to request a distinguished speaker from Huntsville, Alabama to speak in Worcester at their expense should Worcester decide to explore or endorse the idea. As a speaker or person recruited to run teacher workshops, the chapter council has in mind someone who has been part of a network of retired engineers calling for the construction of facilities of this type. He or she will be able to explain the experience elsewhere and make the case for a New England initiative along these lines.

We also suggest that future WPI concept development teams contact the Goddard Space Center in Maryland to see if additional support can be obtained from NASA if it honors their namesake a hero in the field that happened to start here. A moon base is exactly the kind of spark Worcester needs to become the regional center of industry designed to develop an Earth/Lunar trade system.

Four Hundred Years ago New England was a point of contact between the old world of Eurasia and the new world of the Americas. It developed from colony to become a center of a new sea-faring trade. Now it is time to become a space faring nation, and Worcester can be the New England leader, despite the fact that Florida, Texas and California all seek to dominate this new industry and have an edge in the traditional rocketry side of this field. The New England specialty should be the economic exploitation of alien environments using semi- autonomous robotic systems and the creation of human habitats on these other worlds. This is the long term growth field, the

centers of chemical rocket expertise probably face likely obsolesce as new space drives and means of space transportation are developed.

## A Study of the Feasibility of the Proposal: Worcester Science Teacher Reaction

The document to follow which describes a future trip through the proposed lunar base exhibit is not entirely our work. It looks back on the current period from a time in the future when what would become LUNACORP was emerging in Worcester. We adopted this idea from a similar document written by the prior WPI project team of Tyler Flaherty, Matthew Phillips and Hubbard Hoyt.

Flaherty et al. (2007) were actually not doing a space oriented project. They were asked to consider uses for the Worcester Auditorium by EHANA a local neighborhood association that was concerned about the lack of a plan for that public building on the edge of their community. The project team found that one of the school committee members in particular found this "lunar base" proposal interesting and asked that another team be recruited to look into it. We are that team, and we note that the school board committee member who indirectly created our project felt that the idea had merit whether or not it was housed in the Worcester Auditorium building. Hence, we have tried not to be too tied to that site, while making a case for putting it there.

Our use of the scenario was to find out how the science teachers of Worcester reacted to the idea. Hence, a copy of the Flaherty et al. document ( the original is to be found in Appendix C) was edited by us to reflect more precisely what we were proposing. This document was given to Joseph Buckley, the Science Coordinator of the Worcester Public school to try out on a gathering of his science dept heads at a monthly meeting that was already scheduled. He decided to distribute bundles of the description to each chair of a secondary school department as ask them to pass them out, gather comments and pass them back to him or to send to us. About 6 dept chairs out of a group of 18 present at the meeting followed through on that process, or at least that is how many sent packets of teacher comments which were later described to us. Two were at high schools departments and the rest from elementary or middle schools.

In general the idea of a space theme was well received though 2 teachers out of about 25 though another one such as the environment might have broader appeal. Most teachers expressed personal interest in space and a few were concerned that they would find the theme more interesting than the students, but most expected this to be a popular theme among the students. The idea of the colleges supporting the science education mission of the public schools in a sustained and systematic way was very well received, and theme was a secondary consideration for most teachers.

On the other hand the teachers had strong feelings about the idea of doing the exhibit without a coordinated curriculum or just the curriculum without the proposed exhibit. It was the combination that they liked, and either one, in isolation, was probably not worth doing. They were particularly clear that the exhibit without a curriculum would not have their support and the curriculum would not be especially powerful

without the visual and conceptual power of the exhibit. About one teacher per school was sufficiently enthused about the idea to volunteer to serve as a point of contact and serve on a steering committee if the proposal gained official support and went forward.

We also found the document describing a class visiting the proposed exhibit in the future to be useful in communicating what we had in mind with the head of ETA, an administrator at NEAM, a few elementary school principals and AIAA leaders. It was even a handout at one of our talks. Hence, as we describe reaction to the concept it is appropriate that readers look at the precise stimulus document we used in eliciting these reactions from various audiences. It was not used with elementary school students – but did influence our thinking about the model we built and showed to them.

**The Simulated Moon Base as a Cooperative Spiral Education Project**
By Justin Linnehan, Nicholas Wheeler, Patrick Nietupski, Nov. 2030

It was when I visited Lincoln Square in Worcester, Mass., Robert Goddard's hometown, in Nov. of 2012 that I first caught a glimpse of what we at LUNACORP are trying to build on the moon by 2050 would look like. By then the students of WPI, Clark and a few other New England colleges had finished building a proposed mockup of what a sustainable and profitable lunar base would look like, based on what was known at the time. Our major R and D laboratory and the ground control facility where Luna Corp employees operate semi-autonomous robots working on the moon are still located in Worcester, near WPI.

The mock moon base was set up "temporarily" 2010-2014 in the old vocational high school building in Lincoln square. As we all know, it moved to the basement of the

renovated Worcester Auditorium in 2015 when NASA funding became available to upgrade the display and make it a New England Regional Facility rather than just a cooperative project of the public and private schools and colleges in and around Worcester. Since part of the cellar of the Auditorium was not excavated back in the 1930's, one would later arrive on the Moon from an orbiting space station by space elevator. Once on the "surface" one would enter the base via a recently dug tunnel lined with glassified lunar dust. It turns out that the moon dust, called regolith, is an interesting mix of silicon, metals and gases, mostly oxygen. It you microwave it you get this fascinating dust free surface of colorful opaque glass, but that was all later. Things were simpler in 2012.

I went with a group of 8th grade students the "Goddard-Kennedy moon base" on their second trip to the facility. They were "veterans" coming back to help run the base on their second tour of duty. The first tour had just been a general orientation to the geology and geography of the lunar environment with a "visitors" (don't touch the controls) tour of the base itself. This time they would be on the second rung of a "spiral curriculum" in which they would be working in the regolith excavation unit. The students told me they were looking for Jennifer, a Clark Student who had come to their classroom and recruited them to her unit. She was a construction robot repair technician and their team was assigned to bury a newly assembled module under ten meters of regolith to provide cosmic radiation shielding. (In real life she is a double major in Educational Psychology and Interdisciplinary Space Studies with a concentration in human-machine interfaces.)

About thirty 8th grade students were gathered in a second floor room of the Auditorium. The Clark student named Jennifer was dressed in a technician's work suit when she welcomed them to "a space station orbiting the Moon". Soon we were loaded into a mockup of the RISD Lunar Lander (built into a freight elevator) and told to "suit up" properly for the airless, 1/6th Earth gravity into which they would soon be arriving. I learned that this was one of 10 groups of 30 students from all over New England scheduled to visit on this day. My travel companions were "buzzing" as they had just come from a talk by UN officials based in the old courthouse across the street. Someone had told them that the Moon was going to be as important to Earth economy in the 22nd century as the Persian Gulf is in the 21st.

The group of 28 students, their teacher and I went down two floors to a soft landing and stepped out into a 180 degree view of what the surface of the Moon would look like at the South Pole. We got out of the "Lander" to load into a car that takes you into the underground moon base. We were told that cosmic rays require that the habitat part of the base for plants and humans be buried at least 10 meters deep. We walk into a tunnel, lock a door behind us and enter the tunnel car. The top is closed and "pressurized" and we travel sideward into and through the base without leaving the car for 50 yards. During this time we passed by a side lit greenhouse in which we saw several lunar botanists working with Earth plants. Somehow the WPI students had figured out how to get solar energy under and into the building basement and we were in an underground greenhouse. Our guide told us we could not breathe that air as it was optimized for plants that like a lot of CO2, not the Oxygen rich air we breathe. The

command center, with an animal optimized atmosphere suitable for breathing, was the next stop.

The college students tending the plants in the greenhouse all had on masks fed by tubes coming down from the ceiling so that they could operate in this place where white potatoes grew twice as fast as usual and yams grew twice as big as they would in normal Earth biosphere.

Then we passed into the human habitat and there were only a few plants around and they were mostly decorative. We were told that the oxygen in this area was produced from the CO2 taken in by the plants we had seen. The CO2 produced by the breathing humans was gathered and piped to the plant unit. There were several interesting exchanges going on between the plant and animal units such that nothing was really a waste product to be disposed of. The 8$^{th}$ graders learned that there were some animals in with the plants, earthworms mostly, but that the "farmers" mostly kept track of the microorganism world in the plant unit. Potential plant diseases and nitrogen fixing bacteria was the key to managing a plant habitat. It was soon clear that the human race was not going anywhere in space without its partners in life of Earth from the plant world.

I was really impressed with the unexpected ecology/biology lesson. The students were also interested in the fact that many occupations, like geology, here on Earth had useful applications on the moon. The illusion was complete. We were in a moon base designed for 30-50 people complete with underground agricultural unit designed by students at WPI in 2010 and built by some of the college and high school students in 2011-2012. Jennifer let us look through a window at 10 WPI students who were the

construction crew building a new unit and we discovered that half of them were from the AFROTC unit at WPI, and had committed themselves to a 6 month underground stay. They were part of a study by the Biology Dept at Holy Cross, the Psychology Dept at Clark U and the U Mass. Medical School on the effects of isolation and stimulus deprivation funded by NASA. We could peek in at them, but they could not see us. The other 5 WPI students were the people who "delivered" tools and supplies to them for their work- their only "in person" links to the outside world and they showed up only once a month. The 6 in the study were in such great isolation that they normally had only "radio" communication with the outside world as they ran a simulated science outpost on the far side of the Moon.

Jennifer explained that our job of moving regolith was to prep for the module that the isolated WPI students were fabricating. Upon hearing this, the students began to bust with excitement, they couldn't wait to participate in the expansion of the base. Jennifer led us to a control room, where, she explained, the students would be able to command the excavation mission. Divided into smaller groups, the 8th graders worked as a team and guided the excavation robots to remove regolith from the area. Jennifer explained that it was important to be precise so the area would fit the dimensions of the module, but not be so big as to "put the robots through more abuse than they need." After a successful mission it was time to return to the command center for de-briefing and a return to Earth.

During the "debriefing" the 8th graders had all kinds of questions about the machines and the new module. The students wanted to know exactly how the robots and

additional modules were built, and how they were powered. Jennifer tried to answer all the questions but time had run short and she knew all their questions had not been answered, but if their class in school wanted to stay involved they could set themselves up as another science base at another point of the moon, or in a space station and communicate with the students living in or running the Space base. In particular, the Interdisciplinary Space Studies Majors of the Worcester Consortium were looking for "the other 90%" of the lunar work force. She explained that in a lunar factory taking advantage of the near vacuum conditions for production only about 10% of the work force would be on the Moon. The other 90% would be on Earth manipulating semi autonomous robots on radio control with instructions going back and forth at the speed of light. That meant it would be 3 seconds between giving a command with a joy stick and seeing what happened on your computer screen, Enough problems were anticipated that 10% of the "workers" would be on the moon at any given time, but most of the time, you would be able to live in Worcester and be employed by Luna-Corp as a factory worker.

Once they were "part of the lunar economy" they could ask questions of any of the 3000 other people in the network as long as they were "in role". As a "sister" site, they would be given a job to figure out how to do and put in Email communication with Goddard-Kennedy Base in Worcester. Then the Consortium of Worcester College (COWC) students in Worcester, even the ones in simulated isolation, would be accessible to them and answer all their questions about science, work and life on the Moon. The teacher looked a bit overwhelmed and asked if a WPI or Clark student would be sent to Fitchburg to help him get set up. He was assured that that was possible but that he could

also recruit some Fitchburg State students to come to Worcester for lunar production training in a special evening course set up at Worcester State College for the purpose.

## Educational case

The simulated lunar base on its own would be an impressive display, but this barely taps the potential it has as an educational resource. If the base were linked to studies that took place in the classroom, students could see what they are learning. As it stands now, the science curriculum of the Commonwealth hardly scratches the surface of space science. This field has taken on a diminished role in public schools because of the cost of spaceflight, other emerging sciences, and NASA's lack of direction. However, with the world now eyeing the moon as a potential resource, we have a direction, one that will open a myriad of new and exciting career opportunities in an expanded space industry.

The new industry will incorporate more than rockets. It will require civil engineers and construction managers for laying down sections of base, biologists and medical researchers to sustain humans and other Terran natives (plant and animal life) on the moon, materials engineers for new fabrics, economists and insurance actuarial specialists to calculate a lunar economy and assess risks, interior designers and psychologists to make the moon seem more like Earth to potentially sick or homesick Earthlings. The interdisciplinary list of specialists the new space science and space industry will need goes on and on from robots to agriculture, management to medicine. It

goes on because we're trying to build a place for humans to live: a second, smaller biosphere than planet Earth. The majority of the work would be done from Earth and nearly everything we have here we could use there in some form except for fossil fuel based technology.

This new civilization will either have to be powered by the sun, the next generation of nuclear power, or both. At the equator lunar days and nights are each 14 Earth days long. At the poles one has nearly continuous daylight. It is a very different place from our home planet. The case for developing nuclear power in such a setting is even more compelling than it is on Earth.

To prepare students for this future economy, an excellent pairing is the base and a spiral curriculum. The spiral curriculum would involve a short section of the semester taken out to talk about how the subject learned can be related to space. Every year, the classes would have a field trip to the mock lunar base for a hands-on learning experience. Earth sciences, astronomy, biology, physiology, chemistry and physics can all be used in space, and also on a lunar base. The goal of this curriculum is to keep showing students every year the importance of space and the viability of using all of their newly learned fields in that environment.

For a unit where the students learned about earth sciences, such as rock formations and tectonic plates, could spend two weeks learning about the composition of the lunar surface as it relates to the information learned about Earth. This would comprise of learning about lunar regolith, which is the dusty dirt on the lunar surface. The trip to the mock lunar base could include learning about the difference between Earth dirt and simulated lunar regolith, and learning about the importance and usefulness

of the real regolith which arrived on Earth for the first time as a result of the Apollo program..

For the subject of biology, students could learn about the question of life on the moon, as well as what clues scientists look for when searching for life. They could also learn about the different microbes that could survive on the moon, and also about the different requirements for both the moon and Earth. The trip to the mock lunar base could include descriptions of what types of life are best suited to live on the moon, as well as some magnified pictures of an imaginary microbe that had the potential to be in the lunar soil. It could also be used to describe what type of biosphere could be created on the moon, and what type of plants would be best suited for growing in the lunar environment.

Physiology is the study of how the human body works, and that subject is easily applied to the study of a lunar environment. The fact that the moon has $1/6^{th}$ the gravitational pull as the Earth could be enough to warrant an educational visit to the simulated base, just by looking at the effects it would have, such as decreased bone density and muscle fatigue. However, the topic of increased solar radiation and others would certainly also be deserving of a trip to the mock lunar base, where there could be cutaway models of a normal human femur and one designed to approximate that of an astronaut who has lived on the moon for a year, so the students can see the difference. At present we have only the cases of actual astronauts who were in microgravity for less than a year to use as a basis for this guesstimate.

For students who have been focusing on a year of chemistry, they can learn about the relation between human respiration and plant photosynthesis, and how it can be

recreated in a lunar environment. They can also learn about the effect that nitrogen has on plant growth, and how it is necessary for healthy plant growth. For the trip to the mock lunar base, the environment of the base will show them that because the base will need to be underground, there are inherent difficulties in plant growth, because it is not as simple as growing them in the open surface under a protective atmosphere.

For high school seniors who are studying physics, the lunar environment is a perfect way to cement understanding, by changing some of the things that humans take for granted on Earth and taking them to the moon in their minds where they can't assume them. . They can learn about the orbital dynamics that are governed by physics, as well as the effects that the low gravity will have on the base. At the mock lunar base, the students can see how the orbits of the planets work, and they can also see how humans will actually get to the moon. They can learn about the rockets currently used as well as ones being developed and can also learn about the physics behind leaving Earth's orbit.

The spiral curriculum is a powerful tool to combine with the base. It would give students an understanding of space, the jobs that will emerge from the new space race, and then they will be able to see and touch the things they've been learning about without traveling to the moon.

When we contacted the AIAA about sponsoring Kiker to visit the public schools and speak with the teachers, the organization asked Joe Buckley, the science coordinator of the Worcester Public Schools, if he could produce an audience for the Kiker visit. Mr. Buckley gathered data on teacher responses to the idea of the lunar base and the spiral curriculum as part of a plan to assess interest in this event. The teachers were excited to meet with Kiker and there was an overwhelming positive response for the project.

Responses from teachers suggested space was a good unifying theme for a spiral curriculum and many volunteered to take the lead as liaisons for such a project.

A date was set for the teachers to meet with Edward Kiker, but due to a massive snow storm and Kiker's short stay in Worcester, he was never able to meet with them. He did say, however, that when they were ready to tackle the idea he would be willing to serve as a contact person and help the schools organize for the project.

Based on teacher response to our written scenario, we can still say that there is enthusiasm to move this idea along and there are even those that said they are willing to help. The teachers are key resources both in developing the spiral curriculum and making it happen in practice. Given their enthusiasm for a curriculum supported by an exhibit, Worcester should begin exploring the ways to make this happen.

## AIAA Conference

We were invited to the Saturday section of the AIAA Region I Young Professional and Student Conference on November 22, 2008, to give a presentation on our proposal for building a simulated lunar base in Worcester. The Saturday section was for the Educators, while the Friday section had been for the Students. The reason our group decided to deliver our presentation to the Educator section was because we were discussing the spiral curriculum, and we thought that the teachers would make a more receptive audience, as well as our target audience. We were given a thirty minute time slot to deliver a PowerPoint presentation, and we discussed many of the reasons why the moon will become an important part of the future job market. The reason that this

opportunity was so important was because the AIAA is a national organization that has over 30,000 members. With this amount of people comes a vast resource pool, and we hoped that they would be interested enough to potentially contribute to our project.

First we discussed why the moon was important in the first place, and named a few of the important resources that were available on the moon, such as Liquid Oxygen, Helium-3, Iron, Aluminum, Platinum and Chromium. We showed the teachers that 20-30 % of current aerospace engineers will reach retirement age in the next 3-5 years, and that the most senior (immediately post-Apollo era) engineers are carrying the dream of space exploration. Also, because the field is expanding, students will have an easy time finding a job in the field. We also told the educators about NASA's plans to make a lunar base in 2020, and that their current students will be in a perfect position to get job in this market.

The main point of our presentation was that a simulated lunar base in Worcester would be ideal for hooking the younger generation onto this growing field. Using the spiral curriculum, the students could go to the base every year as a capstone for what they learned in that year. We also discussed how Worcester is the ideal place for such a base because of the size of the Worcester Auditorium, the central location in all of New England, the Goddard legacy, and the fact that there are many colleges in the area that can help with the base and the education of the younger students.

The reception of our presentation was generally positive. The teachers seemed genuinely interested in the idea of having a simulated lunar base in the area where they could bring their students on a regular basis. One of the questions we received was about how we were going to pay for the simulated base, which could be accomplished in many ways, such as government funding, private donations, or even corporate backing. As a

whole, the AIAA Region I Young Professional and Student Conference helped our group to put out feelers about our idea and to start to spread the message of its importance.

## Doherty High School's After School Club

The first iteration of our project in terms of delivering the message to actual public school students was in a special unit at a local high school in Worcester. Doherty Memorial High School on Highland Street was the perfect school for our project. Justin graduated from Doherty and was involved in the Engineering and Technology Academy and knew the science teacher in charge of it.

Doherty has implemented an engineering curriculum known as the Engineering and Technology Academy (E.T.A).Briefly stated, some of the $9^{th}$-$12^{th}$ grade students are involved in the academy, while the rest of the school goes through a normal high school science curriculum. An E.T.A. class does not quite break apart after class periods. Homerooms typically stay together taking the same classes together.

The E.T.A. implements one engineering class per year, as part of a regular course curriculum for high school students. There are four engineering classes over 4 years. There is the introductory class during freshman year, the Civil Engineering class sophomore year, the Electrical and Digital Engineering class junior year, and a design project completed during senior year.

However, the one thing that rarely got discussed in these classes was what a technical career is like and the range of possibilities available. In order to remedy this oversight Kathy Kambosos, a lead teacher in the program had asked prior WPI IQP teams

to run an after school program along these lines, but also involving hands on project activities. After three years of a successful program, twice by students advised by Prof Wilkes, but most recently by a team advised by Professor Stafford, the club was in trouble since no WPI team or advisor was interested in running yet another IQP along these lines.

Hence, Prof Wilkes asked if we thought that doing so would be compatible with our project goals? We wanted access to students to try ideas out on and help us build a lunar base model to take to the New England Air Museum (NEAM) for Space Expo 2009, so we accepted the offer. In return for this access we were expected to recruit WPI faculty members to talk about other fields in the technical professions after the space unit was over. Unfortunately, we did not keep this promise, but it will become clear why this was moot after we describe our experience working with the ETA oriented Future Careers Club at Doherty HS. In prior years this club had attracted 20-30 students to its weekly meetings.

In C-term, our group took the stage, for the first time at the reactivated Future Scientist and Engineers Club. We thought it was clear that the expectations for what happens in this club would be different this year, ( see attached publicity poster), but somehow the group of about 25 attendees, which we put into groups of 3-4 was not expecting what we had to offer, and subsequently did not return for more. The group in the third meeting was half the size of that at the first.

As noted earlier, this club was restarted for our project, and we were clearly not meeting their expectations. The prior year this project was advised Ken Stafford, and the club had a Rocket/Robot theme, and related activities, so we thought the space theme

(related to rockets) was a proven winner. Actually, the prior year's turnout had concerned the sponsor. In the years that Prof Wilkes had advised the project the goal was to increase female participation in the technical professions. At least 40% of the participants had been female students, though boys outnumbered girls 3 or 4 to 1 in ETA.

Professor Stafford had been more interested in total participation and had not done anything to change the "image" of the technical professions by stressing environmental and bio-technology themes that disproportionately appealed to the females. His team did a traditional program and female participation dropped back to the existing ratio in ETA. We felt the space theme could include a stress on "female friendly" fields and still do a classical technical field with lots of opportunities opening up in the future. This was not a success.

The students the year before had viewed this Club as having been oriented towards mechanical engineering, rather than space per se. Our program had a space theme and was not an exposure to a different field of opportunity each week. We not only failed to increase the appeal to females, but the total pool of participating students dropped off fairly rapidly to half and then a third the size of the program the prior year. Only the turnout at the first meeting rivaled the average turnout the prior year. Did this mean that the space theme did not have enough appeal to carry a spiral curriculum in a science program?

In each of the prior two years, the Future Scientist and Engineer Club at Doherty HS was one of 5 such efforts to set up Clubs at all the high schools in Worcester and in both years the Doherty Club was the most successful. That is in part since it could build on the existing school within a school at ETA. It may also be because the club started

there a year earlier than anywhere else, so the first year, when average turnout was about 15-20 and heavily female had already been weathered and it was an established club when the others were in their startup year.

In the other high schools there were academies dealing with career lines, other than engineering, such as health at North High, art at Burncoat and government and teaching at South High. The Vocational HS was a special case as the "Club" was part of a physics class for those few students considering college, and not an after school activity. Successful at Doherty had meant an average turnout of about 30 high school students, but this was not typical at the other schools, some of which were considered to have had "successful" programs, especially those at North and South High. Other programs that were relatively successful, given that they were operating under less favorable circumstances, managed to keep average turnout at about half what it was at Doherty. Had the programs lasted another year it might have been possible to see if they would grow to 30 from that base had they become established in the first year.

Now it was our turn to try to establish what was essentially a new program grafted onto the base developed over 3 years at Doherty. We began C-term 2009 with some planning. First we had to figure out when the club could meet and what we would be doing with the high school students. We created a small curriculum for the students to follow. We would teach a different subject of engineering each week but keep it in the context of space and the needs of a lunar base and give the students a hands-on activity to complete, as was typical of the ways things were done the year before.

Some planning questions we considered dealt with a lot of different issues. For instance, which subjects should we teach in what we expected to be a 3-4 week space

series in a 7-8 week program? Can we keep an interest of both males and females? How do we keep them interested if we are running what amounts to a space club, as opposed to exploring future technical careers club featuring a one shot look at 8 different fields?

The most ambitious space event in the prior Future Scientist and Engineer Club program had been a one day field trip for club members to WPI in which they got to sit in on a space oriented student conference for about an hour. There they heard about WPI projects done by students interested in this field. Even then half of the talks had been on fusion energy more generally rather than space in particular. In that case, the HS club students reported enjoying the campus tour and talk by admissions more than the space conference. How would we fill the gap between engineering applications and the lunar base model?

In order to answer these questions, our group developed an agenda. The agenda indicated the date of the meetings, and the field of engineering that we would discuss and teach about each week while developing the overall theme. We would implement a general overview of the field, and then give the students a hands-on activity that would involve building structures or systems. The students would then build these structures as if they were being built on the moon. For example, the first day discussed civil engineering. We taught the group of students about what civil engineers do, and then gave them the task to break into groups and build buildings that a lunar base would have. These buildings were made out of candy, and are pictured on the next few pages.

The second class was to have a distinguished speaker, Edward Kiker come and speak to the students. Unfortunately he was not able to make it on time due to flight delays associated with a blizzard. He got to Worcester 2 days late and missed the club

meeting. Further, he could not stay until the next one, so we arranged to have him speak to a different group of Worcester HS students at South High, where Robert Goddard went to school.

Future Scientist and Engineer club
Luna Corp

Here at Luna Corp. we are in need of engineers to design and build a mock-up lunar base. We will discuss current engineering fields and their applications on Earth as well as the moon. As the future comes closer, so do the opportunities in the job market.

We will be learning about many devices and different types of machinery. As engineers, we will work in teams to build prototypes of these machines and devices out of candy. As the engineer, you are allowed to keep your final product. Applying your creativity has never been so fun!

During the project we will explore the engineering fields of biology and agriculture, electricity and robotics, and civil and environmental. We will talk for about 15 minutes to educate the students about the respective topics during a given class (via power point presentations), and give them about 45 minutes to design and build the components for a functional lunar base. The schedule is below; each class is one hour of fun!

2/24/09: Introduction and Civil/Environmental Engineering
- -Free Pizza!!
- -Introduction of projects
- -Water and Waste systems
- -Structural systems

3/3/09: Guest Speaker
- -Edward Kiker, of the A.I.A.A., will give a speech about the space race, and continuing the dream of space exploration to this new generation of students and engineers

3/10/09: Vacation (no meeting this week)

3/17/09 Biological/Agricultural Engineering
- -Farming
- -Irrigation systems
- -Food processing

3/24/09: Electrical Power and Robotics Engineering
- -Energy sources

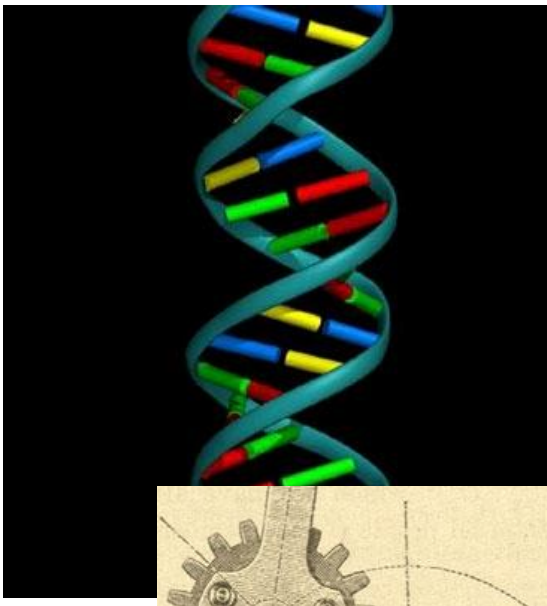
-Automated devices
-Power conversion

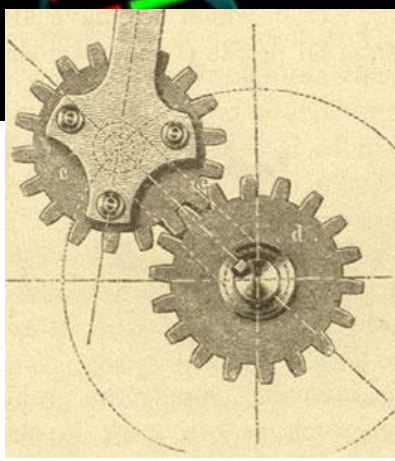
The Students will have their knowledge of engineering applications expanded through the exercises and information that they are given in the Luna Corp club. We will use a hands-on-approach to a few key fields of engineering. In groups, students may work on the subtopics listed as they wish.

Before the club started up again, we had to advertise for it. This was done with a flyer we designed and announcements in the afternoon over the school's intercom system. Our flyer is shown below on the next page. The announcements were made by a Science teacher and coordinator of the E.T.A, Katerina Kambosos. Ms. Kambosos supervised the high school students during the club meet.

Any of this stuff
look interesting?

Like Biology,
Mechanics,
Or Construction?



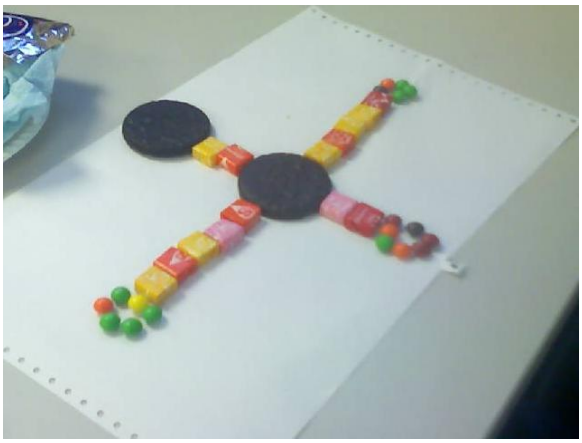


Want to know how today's fields will be applied
in tomorrow's world?

Think about joining the
!!!Future Scientists and Engineers Club!!!
Tuesdays Afterschool
First Meeting Tuesday, February 24th
There will be Pizza!

After the first day, when we did have  a turnout typical of the prior year, our group took pictures of some of the model lunar bases. The students successfully interacted with one another and come up with some interesting creations and ideas. Some of the groups focused only on certain systems of the base. For instance one group made solar panels from the candy wrappers, while another made a very elaborate setup with buildings and facilities setup in a radial fashion. The pictures are shown below. The candy pieces used are mainly Starburst™, Peppermint patties™, Skittles™. The students built model facilities that would constitute the components of a lunar base. These may include power generation, agricultural, waste management, living quarters, launch pads, etc.

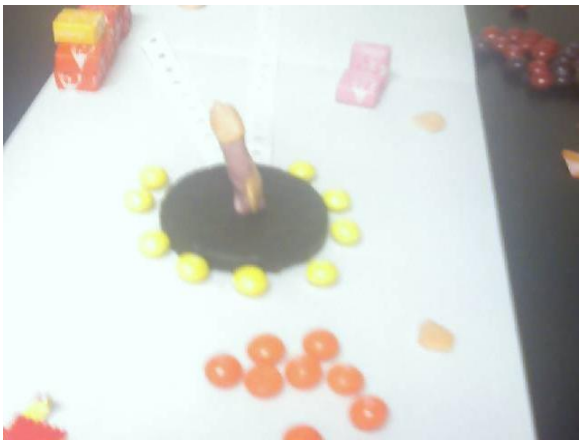
This is a picture of a base by group 1. The students created a launch pad, communication center, and habitat area out of peppermint patties™ and Starburst™.



This is a picture of a base by group 2. The base has a simple setup with a central building, and four facilities surrounding it

This is a picture of another base. It has a simple setup with a central, two story building.

This group made a solar collector for energy. The skittles fell apart from each other, but they were supposed to represent some of the components of a panel. The starbursts were used to hold down the wrapper.



This group focused mainly on a launch pad and made a rocket to go with it. They molded starburst pieces into the ship and used a peppermint patty as the base. Skittles surround the base and represented fuel storage, supplies, and other modules for a departing/arriving ship.

This group created one of the more intricate bases. The peppermint patties and starburst represent living and working facilities. The skittles represent tunnels connecting the facilities. The wrappers on top of the buildings represent solar panels.

This group built a very small very simple model with very little effort.

This group built one of the more intricate models with a central living area and surrounding facilities in a radial array. Starbursts represent the facilities, and Skittles represent the tunnels to get to them.

This group focused on a few components of the base. They made a small ship out of starburst and a peppermint patty (seen in the background). In the foreground, there is a solar panel array made of candy wrappers.

This last picture shows another of the more well planned and organized bases. Five peppermint patties topped with starbursts or skittles represents some different facilities.

During the second meeting, the students were supposed to hear from an AIAA distinguished speaker, named Edward Kiker. There was an announcement about his visit at Doherty and was as follows:

Edward Kiker is the General Engineer for the Office of the Chief Scientist, US Army Space and Missile Defense Command. He will be coming to speak to the students of the Future Scientist and Engineers Club on March 3rd. He is one of the leading thinkers on lunar bases.

Also, he will suggest that a simulated lunar base be built in Worcester circa 2050. This would be the spark to enable his generation help our generation work out the problems of how to live and work in the harsh but resource rich environment of the moon.

Unfortunately, due to a blizzard resulting in a flight delay, Edward Kiker was not able to make the meeting and it was cancelled. It was decided a little while after the agenda came out that there would be a class on the 10th of March over the WPI break, because Justin volunteered to go. However, during C-term break on March 10th 2009, he

got sick and couldn't go; Pat and Nick were not in Worcester at the time and therefore could not go either. Instead, a follow up on Kiker's talk about the lunar base was given. Professor John Wilkes and a student of his, Joseph Paollili, who saw Edward Kiker's talk and were given permission to use some of his presentation materials, met with the Club and talked more in depth about the lunar base. Turnout was thin, about 12 students, two of them showing up late.

The attendance for the third club meet was significantly smaller than the first meeting, a drop from about 26 to 13, with attendance and also at this point participation was heavily male, by a 2:1 ratio. It was recorded as follows:

Future Scientist and Engineer club
Attendance 3/10/09

| Name | gender | grade | ETA (y/n) |
|---|---|---|---|
| T. | M | 9 | Y |
| V. | F | 9 | Y |
| E. | F | 9 | N |
| H. | M | 11 | Y |
| T. | M | 11 | Y |
| A. | M | 11 | N |
| V. | M | 11 | Y |
| M. | M | 10 | Y |
| A. | M | 10 | Y |
| K. | M | 9 | Y |
| A. | M | 11 | Y |
| A. | F | 10 | Y |
| N. | F | 10 | N |

The fourth meeting , on 3/17/09, was cancelled, and the fifth meeting 3/24/09 involved another follow up on Kiker's talk and the lunar base by Joseph Paollili, and Professor John Wilkes- in this case the theme being biological as the threat of a solar flare to the people operating a lunar base was explored. The design problem was to consider what a "lunar hopper" that could operate off of regolith derived local resources for fuel might look like. You did not have to get into space, even against $1/6^{th}$ gravity,

but rather needed to do a suborbital hop back to the base and get everyone underground and under a pool of radiation shielding (probably water) within 2 hours,, which is about the time you would have from Earth Observatories reporting a solar flare until it hit the Earth and moon. There was not a lot of enthusiasm for the project, though the problem was considered interesting to think about, by the few students there. In the end 3 teams involving about 8 students worked on design concepts, but they really just got started. Others said they had to leave early and made no progress at all.

At this point it was clear that the idea of having the Doherty Club help design and build the lunar base model that was due to go to NEAM on Sunday, March 29 was not going to work out. There was not enough interest and the focus of the project team became one of turning out the model to depict a combination of Kiker's ideas and our own. After the NEAM event we would turn our attention back to the Club and take the model they had helped us think about in the early stages for them to see and comment on. The case for the Hoppers would be clearer after they could see where they fit into the larger picture.

The next club meeting took place on Wednesday April 1st 2009. The club had been extended for a few more meetings. This meeting helped to re-engage the students with hands-on activities. Justin and Nick were able to attend this day. For the next two classes, the students saw the final model, which impressed the 8-10 students present the day the model was there. Then they did more work on the Lunar Hopper project.
A lunar hopper is a device for transportation on the lunar surface. It moves like a rocket with short, varying-impulse rocket blasts to make the vehicle hop" to its destination. Issues of balance and how to be sure you landed in a place with regolith suitable for

making rocket fuel and where the people should ride all came up. In the background was how to protect the people from a serious hazard and so the activity involved talking about a mix of biology and mechanical engineering, but was considered to be more aerospace design by the participating students. Meanwhile, a WPI team had entered a competition and proposed to design a hopper, and came to one meeting give a briefing and a little advice to the club members. They ended up making the design problem more complicated, but also added some realism to the activity.

There were, as noted earlier, about ten students who worked in groups to design and build these lunar hoppers though they were not always there at the same time. The club was settling into a core group of about 10 interested in space and coming back for more even though this was not what they originally expected.

The final class occurred on May 21st 2009. Our group received feedback on the club, and took attendance, which was at a low point by then, about 20% of the size of the first meeting, but still half females, which was important to us. We had at least made the case that space was an area for interdisciplinary activity with room for all.

Attendance 5/21/09

| Name | gender | grade |
|---|---|---|
| K. | M | 9 |
| M. | F | 9 |
| A. | M | 11 |
| H. | M | 11 |
| T. | M | 11 |
| A. | F | 10 |
| K. | F | 9 |

As for the feedback, the students essentially stated they liked the original syllabus that would have involved broader coverage of technical fields over time and wished we could have implemented it. The students also wanted to see a more hands-on program if the theme was to be space oriented. One suggestion was to build working model rockets.

This idea is feasible, but was not one we envisioned due to our focus on keeping the expenses for the club low, and getting away from traditional concepts of aerospace engineering. Further, we had been told the club did that they year before.

Our experience with Doherty involved many setbacks. Originally we intended to make a table top lunar base with the high school students and implement the syllabus for the club we created. Due to the snow days and class scheduling conflicts of D-term 2009 coupled with a later start on the project in C-term 2009 and the unexpected extension to D-term, our group was not able to work with the students in the manner we intended. We had planned the club with Kathy, on the basis of a compromise. We would have to ensure the students gained some knowledge, or got something of value from the club. We would be able to have it space themed, utilize the spiral curriculum, create models, and have Kiker speak. After the space unit we were supposed to recruit other speakers from the WPI faculty or student body to speak about other technical fields and the kinds of opportunities they offered. Unfortunately it didn't work out as planned. We barely got through the space unit and built the model ourselves in the available time.

We know now that if WPI wants to encourage the creation of Future Science and Engineering Clubs at area high schools there will have to be a broader institutional commitment than recruiting an IQP team year after year. Running such a program at a single school is not a very good IQP experience. However, planning a city wide program and orchestrating appearances by faculty members from every major department would be a worthy project, especially if one was doing evaluation research on the initiative and trying to understand male and female perceptions of engineering and science fields as

career areas. WPI students should not be doing the weekly events but rather telling the depts. how they did and what activities were most successful.

Nonetheless, we got something out of this experience at Doherty HS and learned a lot. We were able to work with students and receive feedback from them and the teachers. We learned how to keep students with some interest in space engaged, and taught them a lot about the moon and its significance in terms of development. They were able to see the mock lunar base that our group ended up building. In short, it seems likely that a typical high school could support a space club, or a chapter of the Moon Society. It would probably be smaller than a Future Scientist and Engineer Club, but would attract students not aspiring to be technical experts as well. There are potential overlaps with an arts program and even drama and creative writing. The question is who would support such a program, as WPI might not see enough self interest in doing so?

We think that the New England Chapter of AIAA, especially if it could generate a gathering of retired people from the field of Aerospace, might be quite willing to help an interested teacher run a space club with a science fiction side. There should also be one or two aerospace events per year in the Future Science and Engineering Club program. One should probably be a field trip to some place like NEAM, with a strong Aero orientation. The other could be more along the lines of our first day activity, or a discussion of the model we created as part of a larger Show and Tell.

## Edward Kiker

It was brought to our attention that Edward Kiker, was willing to come to Worcester to speak about the case for building simulated space bases, if his expenses could be covered. He plans to retire in about 3 years, but for now is a General Engineer for the Office of the Chief Scientist, US Army Space and Missile Defense Command/Army Forces Strategic Command in Huntsville, Alabama working for the United States Army. He has had a long standing interest in space exploration, and more specifically extra terrestrial colonization.

Kiker has represented the Army Corps of Engineers at several international conferences, all the while suggesting that the Helium-3 on the moon is a precious resource that could be harvested to produce energy. (See appendix B for full biography). Mr. Kiker came up with an idea similar to ours, and actually has helped local volunteer groups build exhibits in vacant classrooms in a school that simulated the view from a lunar or Martian base. An estimated 100 students and members of the general public visited this temporary exhibit in two school rooms while it was set up.

Kiker's notion of a simulated base would serve much like an exhibit for the general public to see and he has also helped set up a space museum in Kansas and hopes they will add on a semi-permanent space base exhibit. He was ambitious enough to suggest that there should be a simulated base in every state of the union. Kiker even alluded to an organization of space buffs nearing retirement who know they will not get to go into space that want to do the next best thing and help build a lot of exhibits of this kind, and described himself as a member.

Patrick made contact with Kiker, who was rather enthused at the idea of a trip to Worcester to speak on this subject and to see what could be done in a nearby building that was underutilized and had a vacant basement. In his email Kiker suggested that his "generation is getting too old to go to the Moon and on to Mars, so it is doubly important to get the next generation leaning forward to make it happen." Contact with Kiker showed that he was something of a "visionary" (though respected by his colleagues) on the expansion of the space program and would be a valuable asset to draw from.

Included in his introductory email Mr. Kiker included a guide to setting up a successful "star city" program (Appendix B]) where he provides several steps to getting a base set up in a city. Included are tips on what local contacts to make as well as a few national contacts to help make the process easier.

After encountering his enthusiasm, it was clear that the best way to utilize Mr. Kiker to his full potential would be to get him to Worcester and speak to the science teachers, students, and space enthusiasts here. The AIAA New England Chapter promised to fund the trip through the distinguished lecturer program on the national office if we could make the other arrangements for a suitable audience. Scheduling began in late B term for a Feb event, however it was interrupted by the semester break. Communication was maintained though, with the help of Professor Wilkes, and Mr. Kiker was tentatively scheduled to visit Worcester from February 10-11.

Mr. Kiker was to give 2 talks at WPI ( one for students in a class and the WPI student chapter of AIAA, the other for the New England Chapter of AIAA and the science teachers of Worcester and surrounding school systems) ) , Doherty Memorial High Schools ETA program and Future Scientist and Engineer Club were also interested

and South High School was potentially receptive. The topic of discussion would be on the future of lunar development. Mr. Kiker was to speak specifically about future job opportunities made by the moon, ( in deference to the Club theme) making note that aerospace engineering would not be the only field to benefit from a return to the moon. He was also to explain his ideas on a simulated base for educational purposes.

Unfortunately, inclement weather kept Mr. Kiker in Alabama longer than anticipated. His flight was pushed back two days, giving him an unannounced talk at WPI and making him able to only visit WPI and South High. . Mr. Kiker's talk at DMHS was canceled. This made connecting the Doherty experience to space difficult, but we thought it was still manageable. Mr. Kiker was the keystone to the entire "weave" of the space theme into general career opportunities theme for the Club and in practice, his absence at Doherty dealt a major blow to our efforts there. A further blow was when the date of his WPI presentation to the science teachers of Worcester was changed, and none of them ended up coming to the event at a different time, different day and even in a different location.

The AIAA audience was mostly WPI students and faculty as only a few AIAA members made it in from Boston given the weather. It was taped by WPI student, Joe Paolilli, but the quality of the recording was poor. Our efforts seemed to be coming to nothing as neither ETA nor the Science teachers of Worcester got to hear him speak.

The team did have the opportunity to sit down with Mr. Kiker during his shorter-than-expected stay. We discussed plans for the mock base. Potential resources, how to explain the value of such a project to college administrators, volunteers, and how to get the public hooked on the need to develop space, among other things. Mr. Kiker had ideas

from who to talk to at "NASA's Attic" in Kansas to what to decorate the tables with in the food court of the mock base. Mr. Kiker suggested a space camp, where children could "spend the night on the moon". He explained how fundraising can be done in this field on a small scale.

Mr. Kiker proved to be a valuable "idea man" and future groups would do well to remember him as a potential resource. In the short time we spent with him, Mr. Kiker was able to give many ideas on how to advance the project as well as many other places to go, that we might implement the ideas. However, the main thing that we learned from him was that the High School audience in Worcester can be turned on to space if it is presented to them properly by a real expert.

The process by which we learned this is as follows, we had a chance to hear him speak to a WPI student audience, and then again to a biology class at South High school. He was a hit in both settings, but the South High presentation was right on target as he talked about how he got into this field, starting when he was their age- and later blew them away with what he claimed was possible on the Moon In short, he gave our message, with flair and both the students and the teachers were very impressed and wanted to know more.

The Principal came to meet him 10 minutes after the talk based on what she had heard about it already and the Worcester Science coordinator was there was well, and beaming about the event pulled together on short notice to a typical student group, not a select audience like ETA. Later, Joe Paolilli, studied Kiker's talk and tried to mimic it to both a WPI student audience and the Doherty High school ETA audience. It fell flat,

even with the same exact content. He was not a dynamic speaker with expert authority speaking passionately from personal experience.

Sure, they learn a lot, it was interesting, but they were not excited. Why so different with what one would consider to be a more promising and receptive high school student audience? Is it the audience or the speaker? We think it is both. We assumed that the less knowledgeable captive student audience in the Biology class was less promising. However, they were not thinking about a science or technology career in most cases and certainly not one in a field where they had not heard something interesting was about to happen. Hence, they could be shocked and impressed and they were. They started thinking in new ways and new possibilities and had a role model before them.

In a sense the ETA students were a tougher audience, since they were already relatively knowledgeable about science and technology, thought they knew what that meant. They wanted to be part of some of the technical activity they had heard about in bio-technology, robotics, communications and the traditional stuff. Here comes somebody saying there is something even better on the horizon, and the space buff stuff is met with skepticism by the majority. They heard out the non- experts saying this and then wanted to hear about the other possibilities. When our team did not deliver, but tried to show there is room for people with biological and even non-technical interests too, they drifted away. This was the wrong audience for that message.

So, we conclude that a general science program for the general student body in Worcester, a place where inventers are respected, could have a greater impact than a specialized program for the future scientists and engineers. Further, a general science

program combined with a club that is overtly space oriented and not just technically inclined might produce a real stir in the area. A labor pool that was very attractive to companies interested in space enterprises (ranging from the invention of new space infrastructure devices and robotic lunar mining to space tourism, hotel management and theme parks) could attract startup and space divisions of aerospace companies to this area. That means jobs with a future. .

We are encouraged by the thought of what will happen if someone does succeed in getting the science teachers together with someone like Kiker to plan a science curriculum program around a semi-permanent exhibit of the type he wants to see created. We were not able to get that meeting to happen, but a school administrator planning a teacher's workshop could make that happen with a bit of help from the AIAA. Once the high school teachers are sharing this vision and able to call on inspirational speakers with suitable expertise as well as college students teams for support of activities they plan, the possibilities seem endless, literally "out of this world".

## N.E.A.M. Space Expo and Table Top Model

On March 29, 2009, The New England Air Museum, located in Windsor Locks, CT, hosted SPACE EXPO 2009,an exposition on space to which our project team was invited. The theme of the exposition was, "Discover the Excitement of the New and Future Space Industry!" and focused on presenting some of America's more ambitious plans for space exploration and colonization. Exhibits included a plan for a self sufficient base on Mars, and presentations from Hamilton Sundstrand and Lockheed Martin on the current and future aerospace industry. Joseph Paolilli had intentions of giving a talk on

the “Economic Case for returning to the Moon”. However, in order to do so at an event like this he needed an exhibit to accompany his talk and display on the main floor.

Our original plan for our mock lunar base was to construct something you could walk into and experience all around you. In our discussion with Edward Kiker though, he explained how he built his own table top model first, and how he thought it was important to “talk up” the idea to gain support and sponsors. With this information, we decided to help Mr. Paolilli by creating a table top model that would help him get into the NEAM exposition and allow us to test the public appeal of this concept of a lunar base to parents and teachers, the most likely EXPO attendees. We planned to couple the exhibit with our work at Doherty Memorial High School by having the students in the Future Scientists and Engineers Club work on the model with us. Unfortunately this did not work out due to scheduling conflicts with Doherty and the time frame in which the model needed to be completed. However, the model proved to be an excellent “conversation piece” for the mock lunar base, just as Edward Kiker said it would be.

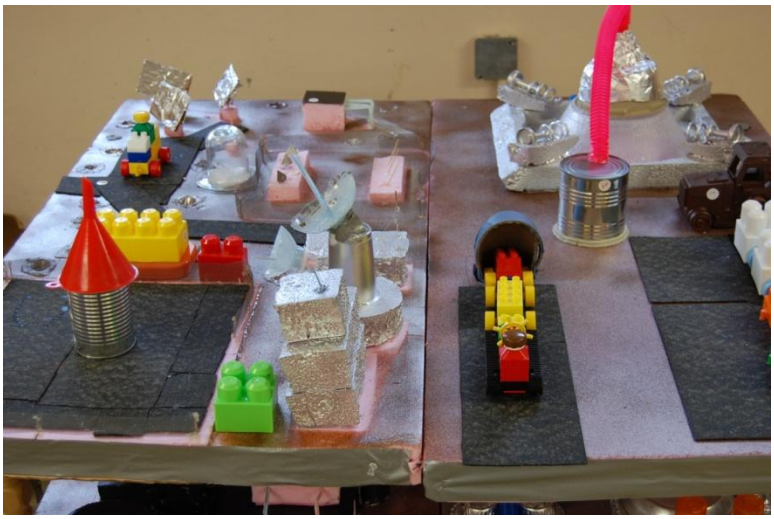
The two talks, Joseph’s and our case for an educational base, blended extremely well and shared an almost symbiotic relationship at the NEAM exposition. Parents, teachers, and young adults could connect very easily to this project, while the space enthusiasts saw the economic merit of the idea in Mr. Paolilli’s talk.

The idea for the model was spawned from the need to have a display at the NEAM space exposition, but it would soon outgrow that one display opportunity Officially we were representing WPI and the New England Chapter of AIAA, but there is a separate Connecticut chapter of AIAA, that is very active restoring vintage airplanes at

NEAM. Since they are not interested in space, and this was a space event, New England chapter was invited to be active on their "turf".

As noted, in order for either Mr. Paolilli or our team to make a presentation, there needed to be at least one display from AIAA/WPI at the exposition. As Professor Wilkes had been to the event the year before, he knew that it had to be pretty elaborate and well developed to get any attention at this event- and it had to appeal to families with children grades 4-8 as well as adults. As the theme was future space industry and both presentations had very close ties to the moon, a table top model of a future lunar base was highly appropriate.

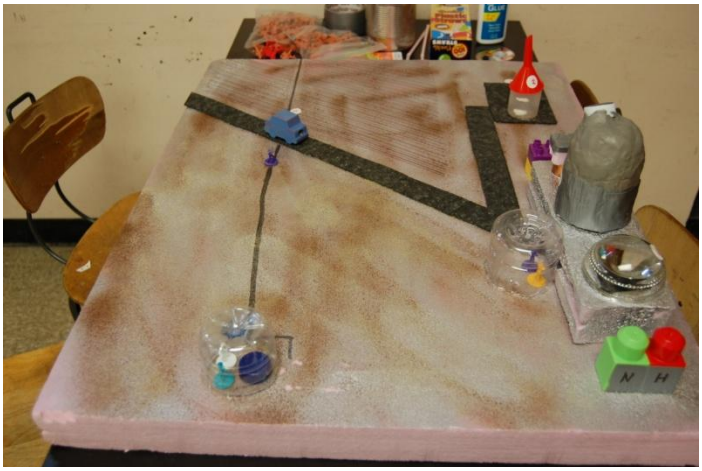
The scale of the model was 72:1, such that a six foot tall human being could be represented by one inch toy figure. It was designed as two levels, the top representing the moon's surface and the bottom representing where the majority of the base would have to be, an underground cavern found on the moon or a crater filled in with regolith. Comprised mostly of pink insulating foam, other materials used in construction include: aluminum cans, plastic straws, modeling clay, plastic bottles, latex and spray pains, and tooth picks. We used a lot of silver, black and blue spray paint as well.



View of upper level.

Side view of model, showing upper and lower levels.

Close up of lower level.



Airial view of away base.

The model was well received by the crowd, especially catching the eyes of the younger audience members. The SPACE EXPO 2009organizers claimed that 1600 people came to NEAM on that rainy Sunday. Many children were asking parents to lift them up so that they might see the miniatures on the lunar surface. Structures represented in the lunar underground include: an agricultural biodome, a recreational and living center, a materials processing plant, water and waste treatment/processing plant, as well as a transit system. Represented on the surface were: a launch/landing pad,

communications tower, asteroid defense station, solar collectors and processors, as well as automated carts and tractors controlled by operators underground.

Originally, small plastic army men with their weapons removed and helmets fashioned from modeling clay were used to represent the average human in comparison to the rest of the base. These were later replaced with the same style of toy, but instead of plastic army men they were actually plastic astronauts by the time the model was shown again in Worcester.

One of the most beneficial things used was the Duplo (oversized lego) blocks. When pressed for time we scrambled to get vehicles on the table top. We used Duplo cars with blocks built onto them and little Duplo men on the front. The bright colors and familiarity of the Duplos drew children to the exhibit. When they asked what the Duplo men were, we explained that they weren't people but rather the "eyes and ears" of the robotic vehicles so that the operators below ground could see what the robots saw on control the vehicles. This intrigued young and old alike and gave us a chance to talk about the hazards people on the surface would face, and where in the base they would go to survive a solar flare.

Of the 1,600 people there, mostly in family groups of 3-5, we spoke to well over 100. The children were the ones that ran to the model, but once they arrived, it was the parents that wanted to stay and learn more about the economic case for building a base on the moon. Our plan for both a Lunar base that could pay for itself as a Helium-3 mining camp was news to them. The idea of a simulated lunar base to prepare their children for a career in a future space company called LUNACORP got them thinking as well.

Upon hearing the plan for the simulated base, many parents perked up to listen about a possible future career for their children in a field that, until recently, seemed to be "heading out the door". Many of the parents we spoke to at the NEAM Expo found the proposal represented by the model to be something that was stunning and thought provoking, even exciting. They were glad to hear a revolutionary idea come from somewhere that was not NASA's modest idea of a costly lunar base that had no economic justification. Some were blunt in saying that they have begun to think NASA has lost both its nerve and its direction.

Accompanying the model was a display board, upon which descriptions of each aspect of the model was labeled. Each description was assigned a number, and the corresponding number was also placed onto the base itself. The idea was to have people try to guess what each part of the base did or was for. In practice most people just asked us, or waited for us to tell them. However, this configuration helped to peak the interest of the younger audience, and was interesting to the teachers who came by as well. A few children reversed things and tried to hunt for the elements listed on the model looking for the number they saw on the board. Other times the numbers would spark the question: what is that?

Many suggested that the idea for a future lunar base is excellent, and would have been better received earlier by the public had such a strong case for a return to the moon been made by NASA. . The strong positive reception of the model at NEAM would eventually prompt our visit to Elm Park Elementary School to display the model again and give lessons about what NASA's plans for the moon should be after 2020, when they

finished the simple base they want to build as part of "Constellation" and one could move in the direction of something like what was depicted in the model.

The formal oral presentations at the exposition went rather smoothly. A small audience of about a dozen people attended both, as they were back to back, however, the twelve-or-so individuals proved to be very interested. First to present was Mr. Paolilli. The audience was interested to hear about the resources on the moon, and as the questions demonstrated, was eager to learn more. The economic case for returning to the moon was followed by Patrick presenting the "Proposal for a Simulated Lunar Base in Worcester" (see appendix), to which the crowd responded avidly. This was something one could do right here and now and they strongly supported it.

An outline of the "spiral curriculum" designed to go with the exhibit was introduced and with it came many questions. The audience was curious as to when children would start the curriculum, how long would each unit last, what subjects would be studied in addition to other things. In short they wanted to get into details before we had worked them all out. It was a warning about the kind of questions an enthused group of teachers, might put to us, and that we had better not disappoint them or worry too much if they had a better idea based on their experience. They want to explore the possibilities and did not seem to really care that we had not thought of everything. In a sense, they wanted to contribute.

One woman, in charge of a group of Civil Air Patrol cadets, was so interested that she followed Patrick out of the presentation hall and out to the model, asking questions the entire walk back to our exhibit table and stayed to learn more while people who had

not heard the talk visited the model and got the 3-5 minute version of the talk, just enough to provoke questions that we could answer in an exchange. The CAP leader what watching audience reaction and became convinced that we were really on to something. You did not have to be an expert, just mildly interested, to get the point of this display and start talking about what the US and NASA should be doing in light of this possibility.

## Elm Park School

Elm Park Elementary School was the next destination of the lunar base model. The activities we planned were for two groups of students. During our first visit, we worked with a large class of sixth grade students. The second visit involved a class of fourth graders, but we were surprised to be assigned to work with the 4th grade teacher that was not known to be interested in space. This was not "Fran" the one who had arranged for our invitation. Still, the program was a hit with the "weaker" 4th graders taught by a teacher not "into" space.

This odd scheduling proved to be a matter of timing, when we said we could be there did not work for the class and teacher we had expected to see. Hence, we returned at a time that Fran's class could participate in the program. As expected, this was a slam dunk over the top success. The stronger 4th graders with the interested teacher loved it. They hoped we could come back the next year. Hence, in the end two 6th grade and two fourth grade classes participated in similar but slightly different programs.

The 4th grade program was an improvement over the first one we did for the 6th graders in that the first time the craft project overshadowed attention given to the model.

The second time the balance was better but the model was the focus. We got it right the 3rd time, and both got the right amount of attention in a 1.5 hour block of time.

The activity we planned for the two classes of sixth graders was still a huge success. The students worked at tables in the school's multi-purpose room. There, we had the base all set up on display. We explained what the base to them in groups of 6-8 at a time, but they were acting like we had interrupted their work and they seemed eager to get back to the craft in progress. Still, most seemed to get what it was, why it looked like that and the concepts behind it. It was repetitive for us but the small groups encouraged questions and we were able to answered many student questions, at least all that they asked, but in some cases we wished people from other groups were there when we got really good questions. Not all groups were inquisitive but some were. We also taught some basic physics for elementary students when we explained how the moon has one-sixth earth's gravity, or how a lunar hopper moves like a bouncing ball.

The students sat down at the tables, and were broken up into groups of three or four, as noted before. The activity we planned for them involved designing a lunar hopper. To refresh, a lunar hopper is a device for transportation on the lunar surface. It moves like a rocket with short, varying-impulse rocket blasts to make the vehicle "hop" to its destination. The concept is described more in depth in the Doherty High School section of this report, but at a 6th grade level the challenge was to be sure there was a place for 4-6 plastic astronauts to ride in a padded place and rockets and a place where the regolith could be process to extract oxygen. The designs ranged from tradition vertical rockets to flying saucers and a few that looked like contemporary art.

The students were provided with bags holding similar sets of scrap materials that were separated into plastic bags for each group. The students were not told specifically what they had to work with as the bags had varying items in them. Some of the items we used were Styrofoam chunks, toothpicks, paper plates, small plastic cups, and play-dough. The students worked eagerly and enthusiastically with the items we provided as well as one another. The teams of students, within a period of two hours, came up with some very interesting results. Some of the very interesting creations are shown on the next page.

The students in this group used a large circular chunk of Styrofoam for the main part of the ship. A large drinking cup and a tube of gray foam make up the cock-pit of the model. Smaller drinking cups and a paper bowl were used for the rocket boosters. Elmer's glue and toothpicks held the model hopper together.

The students in this group made a hopper with a cylindrical card board container as the main part, with straws and smaller cups representing fuel tanks and fuel lines. An aluminum cup cake wrapper was used for a solar panel. This model hopper was held together with glue.

This last model hopper was one of the largest. Again, the body of the ship consisted of chunks of Styrofoam, and a paper plate. Rocket boosters were made with small drinking cups wrapped in aluminum. The cockpit was made of a larger Styrofoam drinking cup surrounded by Popsicle sticks and straws. On top is a communications antenna.

The students clearly valued our lesson and activity for the first meet. The teachers were impressed, and enjoyed what we did with the students for that day. The students

certainly had their own unique ideas about what a lunar hopper would look like, and how it would move. Some students concentrated on specific parts of a lunar hopper and neglecting or were not even considering building other components. For instance in the pictures above, one group focused on making fuel tanks, the other focused on communications.

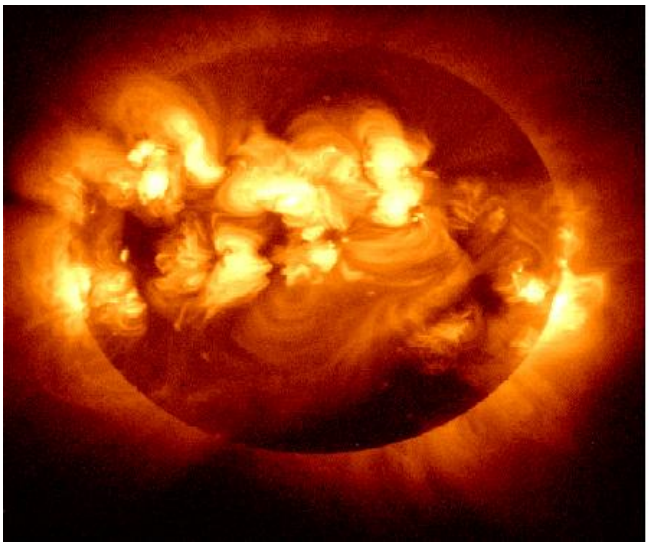
This activity was very engaging to the students because it was very open ended. It was simple in concept, yet was able to expand on the creative and inventive side of the young students' minds. The activity we did with the sixth grade students and the concepts we taught concerning the moon and base, certainly make the case for the need to introduce these concepts into the classrooms of schools.

The second time we went to Elm Park Elementary School, we worked with a class of fourth graders. We brought the model base to aid as both a learning tool and something to spark the students' interest. All of the students first gathered around the model lunar base, where they asked questions about the various parts of the base. They were very interested in it, and were extremely curious about the different sections of the model. There was not a lot of previous knowledge about the subject, but the willingness to learn this new topic was definitely alive and well. They learned from each other and one student in particular seemed to be the local future scientist and even the teacher turned to him to answer the harder questions about what to do to protect the plants and people in the base in the event of a solar flare. This time the emphasis was on saving the plants rather than the people.

The activity we had planned dealt with getting sunlight down from the surface into the agricultural center of the lunar base. In order to illustrate the principle we had

each team try to use mirrors to reflect light down a cardboard tube and around a corner. That was fine for normal conditions however, we were talking about what to do in the event of an emergency. The people would go into a chamber underneath the swimming pool, but what to do to save the plants?

In the event of a solar flare, the entire agricultural unit area would have to be protected from the increased radiation. We showed the students pictures of what a solar flare looked like, so that they had a better understanding of the issue. The picture they saw is shown below.



We talked about using mirrors and how it is possible to reflect light depending on how they are set up, and also that in order to protect the plants from the harmful levels of solar radiation there needs to be some shielding. We also said that one of the ways of doing this was to have a water barrier, since water is a very good absorber of radiation.

We then asked them for ideas on how the plants could be protected from the radiation, hoping that they would make the connection to try to put water in between the sun and the plants. There were a few students who were actually very knowledgeable, but most of them were having trouble with the problem. This could be because they had

no prior knowledge or background in this field, or that they just couldn't grasp the concept, or even if they were just too shy to say anything. There were some that were willing to take a guess but it soon became clear that they were waiting for one quiet student to solve the problem. With a bit of coaxing from the teacher he did speak up and had the answer. He knew what should be done, and his team then helped to teach the other students as well.

Then we had the students break up into small groups to do an activity about reflecting light. We gave each group two small mirrors, a cardboard tube, a flashlight, and some clay for holding things in place. The goal was to imitate a periscope by putting each mirror on one end of the tube, and shine light through it and see where the light ended up. The idea of a submarine periscope did not seem to be familiar to these students, but they soon got the idea of how to side light a greenhouse so that there was 10 meters of radiation protecting regolith between the sun and the plants in the underground growing chamber.

The groups we talked to were very excited to see the flashlight pointing in one direction, but the light coming out of the tube shining in a different direction. They we amazed to find that you could make light go around corners, rather than just cast a shadow. The entire session was a success, because of the interest that the students had for the material and the amount they learned from it. This is a good example of how using space related themes in the classroom can spark interest and ultimately increase the amount learned.

Summing up the experience, we were a hit at the elementary school level and the modest model we had created contributed a great deal to this success. We began to

wonder if the movement toward curriculum change could start with such models and then move to a full scale "walk in" exhibit that we envisioned over time? A lot seemed to be possible with portable show and tells if you have the student's interest, but how to put together and continuing program that did not require training all the teachers at first?

It seems that at one time the Worcester Schools had a gifted and talented student program at the elementary school level called PEAK ( Providing Equity for Able Kids). This program involved about 10 students in each of 40 elementary schools per year. There were only 5 teachers to cover 40 schools, so they went to 20 schools each semester, as we understand it, they were at a different school each of 4 days a week. On the fifth day of the week they met as a group with each other. They seemed to use a lot of portable props, one of them liked to dress up as a historical figure when going to his schools and give speeches in role. The Lunar model seemed to be compatible with that approach, especially if there were 5 of them, one covering how all the major systems fit together and one of each of the subsystems in detail.

The possibility of having the college students build an exhibit for the secondary school students and having the high school students create models to be used in the elementary school by traveling teachers looked like an interesting approach. Now that we could see that a modest portable model was a powerful teaching aid, it was possible to see how to start with limited financial support, if one could draw on a small group of knowledgeable volunteers willing to support a larger group of people who would do the rounds to a few dozen schools each semester. The AIAA could produce a few volunteers but not enough to run all the school presentations required by such a program. The question was whether college students working with them and getting something other

than pay from the WPS (academic credit or some other advantage) could do the outreach part of the effort?

As it turns out, WPI students getting financial aid from Federal funds have a service requirement to fulfill. The organizers of this program are always looking for useful outreach projects that they could do. A weekly commitment of a few hours for 2 months or so would not be considered unreasonable, so one student could run a PEAK style program for one school.

Could 4-5 local colleges working together produce a pool of 40-50 students looking for service projects to justify their financial aid? What would it take to plan and coordinate their efforts? We think this is an interesting way to look at how to meet the resource requirements necessary to have a pilot program that could be used to justify a grant proposal to be submitted to NASA to build a full fledged lunar base exhibit.

## Discussion of Results

This project began with a focus on the public schools and whether a case for building a lunar base exhibit would be worthwhile and ended up back in the schools, though for a while it looked like the opportunity to prepare a display for N.E.A.M.'s Space EXPO 2009 would dominate the project. Through our work done with the public schools we got a glimpse of teacher reaction to the concept and their stress on the need for a curriculum that drew on and built off of the exhibit. Then we got to work with students around the lunar base theme both at the high school and 4-6$^{th}$ grade levels, (at ETA and then the Elm Park Elementary School Students). Meanwhile, we were setting

up the AIAA New England's distinguished lecture by Edward Kiker and making sure that catered to students and public educators and that he got to talk to a general, not self selected, HS audience. Through these activities we learned about student interest in the space program, and particularly a lunar base focused program that could pay for itself over time and be a boost to industry in this area if the Goddard Legacy was embraced.

Though there were times when building the model of the lunar base seemed like a distraction, in the end the NEAM model really seems to have set our project apart. It got a mixed reaction for the ETA students we wanted to help us build it, but once it existed, suddenly it was much easy to communicate with teachers, parents and younger students. Kiker could get the idea across without a model physically present, but even he was showing pictures of one he developed to use at a conference with his peers.

It was so much clearer what was involved in an exhibit that would be viewed from the inside once you had blocked out what the exterior would look like. The students seemed to be having no trouble imagining themselves inside the hoppers they built for 4 little people, or moving around with the little 1-2 inch tall people they saw deployed around the lunar base. We made a serious effort to keep things in scale for the size of the people we had included in different scenes, 1 inch for the away scientific facility and 2 inches for the mining facility that was the center of attention.

We are convinced that a program built around simple and cheap models could develop into a modest exhibit in a few years and then justify funding at a grander scale for the kind of thing we envision going into the Worcester Auditorium basement. The question is how to get from here to there, and what actors need to be involved and what would they have to do, and when. This would require a Worcester City/ Worcester

Public School (that's two different bodies of decision makers and budgets), Area colleges (At least WPI and Clark U where Goddard lived and worked, but hopefully WSC, Assumption (they teach teachers), and U Mass Medical School, and Holy Cross too) and AIAA New England chapter collaboration.

The AIAA Chapter is openly interested in public outreach and encouraged by the national office to support the public schools in the hopes of attracting young people to the field. School- college cooperation is not uncommon in Worcester. Cooperation at the level of the colleges has some precedent so a joint program space studies program that could be a double major or minor with any other traditional major seems theoretically possible, but this would be unusual. A prior IQP study by Boyce (2007) reported that focus groups of students at WPI, Clark and Assumption wish they had more opportunities to get together for common activities, and hoped that a renovated Worcester Auditorium would provide a "college crossroads" space for this to happen. This use of the auditorium would be compatible with our proposed use of the Auditorium. However they probably are envisioning a bus station and classroom and office space (See Appendix C for potential uses of the Auditorium).

The auditorium is a big open space on the first floor and sort of a warren of chambers of various sizes below. The crossroads idea is probably more suitable for one of the two buildings across the street from it, the old courthouse or the Boy's club building that was until recently part of the old Worcester vocational school. Courtrooms could easily be converted into classrooms and both of these spaces are already set up for office and meeting room mixes. The headquarters of the integrated space studies major program itself, should probably be located near the exhibit we envision, but that could be

in the auditorium or across the street from it. There do not seem to be any deal breakers that suggest this level of cooperation is out of the question. However, would the education yield warrant the effort? Would the students be enthused? Here the evidence based on our experience is a mixed bag.

One thing we learned in taking over the Club serving the ETA students was to avoid false advertising even when you are piggybacking on the efforts of others doing related things in the past. When we were asked to come in and keep the Doherty HS Future Scientist and Engineer Club effort alive, we did not make it clear enough to the club advisor that our interest was in space, and hence a bit narrow for this group. On the other hand we had every intention of doing space for a month and then helping recruit people at WPI to do other things. That did not happen when we discovered we had a lunar model to build personally, without help from the ETA students. The Lunar base theme was good for one Club meeting, but not a sustained effort of this kind.

Thus, part of our project turned out to be an experiment to see if any technical theme would do for this kind of self selected group interested in technology or you really needed to do what had worked in the past, provide a survey of career lines to broaden their horizons? We were optimistic that any technical theme would do and we could include many fields of interest in the space base theme. This was not the case. The students were not there for another class or project. They were there to try on several possible career lines for size and that was what the ETA program was missing up to then, and for 3 years groups of 20-40 students would gather to do that. We changed that formula and attendance dropped to 10, about what we think a technically oriented space

club at the school could support on a continuing basis. That might be worth doing, but it raised questions about the viability of a whole science curriculum with a space theme that ran a month at a time for everyone, and to which you would return each year.

Let's look more closely at what happened when we took over the Future Scientists and Engineers Club; was this reaction to be expected and what is the lesson? Clearly attendance and enthusiasm for the after school program dwindled as time went on though there are probably enough people interested in space exploration at the school to have a Space or Model Rocket Club. Our space theme did not catch at the Doherty ETA the way past Future Scientist and Engineer programs involving civil and environmental engineering or robotics had. This was supposed to be a career oriented club with weekly activities illustrative of the problems addressed in each field, and they were not taking to the message that a renewed space program would open up whole new career possibilities for people in several fields.

In a way, this is not surprising, though we were surprised. This was the group of HS students already interested in the technical careers they had already heard about. You were not going to attract them to science and technology careers through the lure of the new frontier in space. They were interested in current kinds of technical careers, and skeptical about all the Maybe's involved in whether the US was really serious about going to the Moon. Would there really be new jobs? Maybe. What else is there and is it a sure thing if I train for that?

By contrast a more general group of HS students in a randomly recruited Biology class at South High had taken well to this message as presented by Edward Kiker, who is an inspiring speaker with a personal story to tell. We never got to find out if Kiker

personally could have “turned on” the ETA audience that we found we could not reach well enough to completely engage them for a full scale model design project.

At first the popularity of Kiker and our flop with the Club (with what seemed like a more promising audience) was confusing to us, but given the interdisciplinary nature of our plan, and the emerging space industry itself, this doesn’t seem so surprising in retrospect. In fact, it fits quite well. Students without the technical intensive background of the ETA students showing large interest in the new possibility for them if they considered technical career preparation, is something new and exciting to consider. The Kiker talk was a one shot event, in place of a biology class, not a continuing program, but it is important to note the good reception it got. We are trying to assess general student receptivity to a space oriented science curriculum. We are not planning to change the ETA curriculum from its current focus on Mechanical Engineering.

It gives us an incentive to keep the idea moving, though there is the issue of can what we want to do, be done, with only normally gifted instructors or without a personal story to tell? It is also important to know that as the technically oriented student sees it, the space industry is a long shot and not as interesting as the electronic and biotechnology fields already well established. Further, if you want to attract women to the field you have to make a connection to themes that concern them, such as health care or environmental protection. Rocket Science does not have the right image for women or broad appeal to the men. Maybe it seems masculine or seems elitist to high school students in a public school.

As noted above, we think that the way to make the mock lunar base idea viable and connected to a new science curriculum is though the collaboration of many different

groups. On the City of Worcester side, we need the public school science and social studies (and maybe art) teachers and the school administration, as well as school committee and the development office thinking of how to re develop the North End of Main street. In addition we need the technical experts, represented by the New England Chapter of the American Institute for Aeronautics and Astronautics and the College based professionals and well as the college students of Worcester, who might be pulled together through the Colleges of Worcester Consortium.

The amount of interest generated by this project makes it worth exploring in the future. Teachers seemed to like the idea. They enjoy seeing students succeed, more so when the success is coupled with the students' interests. There was some evidence that they were up for anything which would result in support from the colleges for their efforts, but the theme proposed did seem promising to them. The idea for the spiral curriculum offers students the chance to explore a subject filled with material that is outside of Earth, and then relate it to their lives today. This is something they would revisit and re-relate to every year.

Imagine: a ninth grade class learns about the material properties of regolith and compares them to similar materials on Earth. The next year those now-tenth-graders are studying a lunar based economy. It trades with the Earth and thus the students take a look at macro-economics. The tenth graders then explore which properties they learned about the year before make regolith worth trading. This is an ideal scenario, and while teacher enthusiasm for and undertaking of this sort is important for it to get off the ground, the school committee must also be on board.

This is a big project, adding a large piece to an established science curriculum and some of it would be considered social studies rather than physical science per se. It is, though, worth examining. Before a radical change is made, observing the potential for a space science program on a small scale is a good place to start. In the early 2000s the Worcester Public Schools ran a program called PEAK (Providing Equity for Able Kids). This enrichment program scouted for a few gifted students and took them aside for more advanced material. Unfortunately, due to funding issues, the program was ended and replaced by a model in which the normal classroom teachers decided which of their students should do special projects. The result was a large reduction in the number of students getting extra stimulation.

However, either model could support experimenting with the spiral curriculum for the space sciences. We think having outsider come in and do it PEAK style makes more sense, at least at the outset. A few gifted students that express an interest in space could be gathered once a week and be given a space lesson. One school, two schools, the entire district; any size the school committee wanted to commit to an experiment or pilot study will yield worthwhile results. If the interest generated at South High School is at all representative of student interest in the district, an addition to the current curriculum should be explored at the secondary level. We think the case for an elementary school program is already made by our efforts.

The New England Chapter of the AIAA is a regional authority on spaceflight and exploration. We think that if it takes the initiative and approaches the Worcester Public Schools and selected colleges, an experiment can be mounted with modest resources, and that it is a reasonable place to start.

When this project group approached the AIAA with the idea, the reception was excellent. We represented the AIAA at the New England l Air Museum (NEAM) in Windsor Locks, Connecticut to see how reception would be from the general public. They were delighted to hear that the attendees were excited about the idea. The AIAA financed the trip for Edward Kiker's visit to Worcester to further explore the interest of students, which is how the enthusiasm at South High was discovered. The AIAA has the personnel resources and credibility to help make this a reality, but not much in the way of finances. They are good for about $1000/ year.

If the school committee and teachers were to work with the AIAA a curriculum could be written that would satisfy what the AIAA and teachers consider being important material as well as what the Commonwealth deems is necessary for the MCAS testing and graduation requirements. Furthermore, the AIAA could then use this as a model to expand the program to other regions in New England, and if these sites were to interact the program would be brought to a whole new level.

Connected with the idea for a spiral curriculum is that of the simulated lunar base exhibit. This base would serve as a place for the students of Worcester's schools to visit, a field trip, to further their study of outer space. The site could also run as an exhibit or museum open to the general public. An excellent location for this lunar base would be the currently abandoned Worcester Auditorium. While the entire idea for a simulated lunar base is not tied to the auditorium, as there is a myriad of abandoned warehouses and closed schools in the city, the location is ideal because of its place in the city, cultural significance, and its size. The auditorium is located close to the center of the city, making it easy to find and get to. It is also a two minute walk from the Worcester Art Museum.

The proximity of these buildings could pave the way for a cultural revival with the much awaited union of science and art.

The auditorium was originally constructed as a monument to the First World War. As it stands now, the auditorium is rotting on the inside and is very seldom visited by anyone. Fifty years of use and then abandonment cannot be what the builders, contributors, or veterans hoped would happen at the site. Reviving it as a monument to the past as well as a beacon for the future is rather fitting. Finally, the size of the auditorium is perhaps its greatest asset. The building is enormous and could easily house a proposed facility of unusual quality. It is so large, in fact that the lunar base could be built in the basement alone, leaving the upper levels unfinished. Another option for the upper levels is to refinish them into something else that is consistent with what is going on at the lunar base, but honor Goddard and his times, the start of the aerospace industry as socially significant. They could perhaps be transformed into a number of things that could help generate a revenue stream.

With this in mind, the missing piece is the finances to repair and refinish the auditorium. An obvious choice is taking it to the city for an appeal for funding. Another, more promising option though, is to approach the Colleges of Worcester Consortium. As it stands, the Consortium is a loose affiliation of colleges that share class space and pretty much keep to themselves. If the consortium pooled resources to start reconstruction of the auditorium, they would own part of the building. The consortium could then turn the upstairs into a crossroads of sorts, making the consortium more closely resemble the Colleges of the Fenway in Boston. The Auditorium could then serve as a meeting place for student and faculty as well as prospective students. This consortium crossroads, about

the simulated lunar base, set only a few minutes from the Worcester Art Museum has the potential to be a major draw of area school field trips to this part of Worcester.

A plan along these lines makes the lunar base and spiral curriculum feasible, with obvious pay-offs to the benefactors involved. That, combined with the students' interest from South High School, merits further study and exploration of this proposal. It is a chance to give students an amazing hands-on learning experience like none other, while simultaneously injecting some techno-culture into the Heart of the Commonwealth.

## Conclusion

A renewed new space race between 3-5 nations seems likely in the 21st century, and the USA is no longer clearly the leader in space technology and science. Further, this subject is currently neglected in most secondary school science curricula. Hence, it is vital that public school students from grades 3-11 in the USA are taught about the solar system surrounding our planet. About 25% of the current aerospace corps of professionals is reaching retirement age in the next few years. This field will need to expand and become more interdisciplinary if the next set of challenges is to be met. By our estimate it is the current college and high school students who will design the first self sufficient and self financing lunar base to be built about 2050. It is current elementary and middle school students who will build and man it. One of the best ways to prepare the next generation is to build a mock lunar base, and have it in an exhibit in central New England. Thus is could serve as a meeting ground between the generation

now retiring out of aerospace, and reflect their plans and dreams, visions and sense of possibility. This needs to be communicated to the next generation of colleges students who would help them plan it and build it. The retiring generation would then also have a chance to work with the current generation of science teachers to help them develop a thematically integrated spiral curriculum and use the associated exhibit as a resource to teach the students still in the public schools about space science and engineering design.

Since this is now rarely taught in the USA, a school system that finds a way to do so is preparing its students to grasp a special and historic opportunity. It could also attract the companies starting up in this field to the area to draw on an especially strong labor pool. This would position Worcester well for participation in an emerging industry.

Why there is currently a gap in thinking and planning this kind of activity in the aerospace community of the USA is long story, but in the end it has to do with the politics of space and erratic funding patterns at NASA and in this field of technical activity more generally over the last 30 years.

Why might Worcester emerge as a leader in a field now dominated by Florida, California and Texas? It could and should do so by looking farther out than NASA and avoiding the prevailing NASA mindset with favors manned space activity and does not seem to be guided by sound economics. Also there is a historical legacy of great symbolic significance since Robert Goddard did his pioneering work on rockets in the Worcester area. Also Worcester has a major asset, a spare building that it has to maintain anyway, to devote to such a project. The Worcester Auditorium, which was built between the two World Wars, is currently underutilized, has a massive basement and is quite appropriate.

We propose that Worcester consider having the colleges and public schools in the city team up to build a mock lunar base circa 2050 exhibit at that site.

The case for doing so, evidence of support for the idea by various key players and the potential long term economic advantages to the city have been explored in some detail. However, it is the story of our own construction of a table top model of a lunar base and the reaction of the public, and students in $4^{th}$ and $6^{th}$ grade that suggests this effort could start modestly and build up to something impressive over the next 5 years.

The project was sponsored in part by the New England Chapter of the AIAA which funded an outside speaker on the subject that we brought from Huntsville, Alabama to speak to local high school, college and professional audiences, and the reaction he got from college and high school students was encouraging. In the end this project was to assess the likely response to a proposal to build an exhibit with unusual educational value and we are encouraged by what we found. A complex collaboration would be required but all the necessary parties seem receptive to the idea.

Hence, this project began with a focus on the public schools and ended up with one, though for a while it looked like the opportunity to prepare a display for N.E.A.M.'s Space EXPO 2009 would dominate the project. In the end the lunar base model prepared for NEAM allowed us to better express and test student reactions to the idea in Worcester. We think that similar model could be the basis for a pilot study of the case to commit to a full scale exhibit and raise $100,000 to design and build it on an impressive scale.

# Table of Appendices

# Appendix A

## Appendix A.1

### Appendix A.1.1

12/11/08
Edward Kiker, General Engineer
Office of the Chief Scientist, US Army Space and Missile Defense Command
Huntsville, Alabama
Dear Mr. Kiker,

I am Pat Nietupski, a student at Worcester Polytechnic Institute. I am contacting you on behalf of the New England Chapter of AIAA in the hopes that you would be willing to come speak at an NE- AIAA meeting hold in Worcester if we can arrange to get you designated as a Distinguished Lecturer of the AIAA. My team of 3 students in one of WPI's many ongoing student projects dealing with society- technology issues is supporting the effort of the local AIAA chapter to have a meeting in which the pro's and con's of building a simulated moon base to support science education are discussed. Our professor/advisor, John Wilkes, met you at an NSS meeting in Washington earlier this year and he tells us that you have experience with constructing educational mock space bases. We would like to know if your experience with simulated extraterrestrial bases would lead you to help us make a case for such an exhibit in Worcester for the New England region.

Our project team has been in touch with the American Institute of Astronautics and Aeronautics and has learned that the national office will pay the travel and related expenses of "Distinguished Lecturers" going to speak at chapter meetings, so if you are willing to come it is our job to make the case that you should be so designated. AIAA New England has expressed an interest in our project, which involves having college

students build a mock lunar base in Worcester as an exhibit for public school children, and the local chapter society will support out nomination of you if you are willing to come speak in February or March. We would like you to meet with local educators in the Worcester Public School system as well as speak to the AIAA membership. The general description of the lunar base as we have presented it to interested local people is enclosed with the attached file. We have told AIAA that you would be an ideal distinguished speaker to lead this discussion, and AIAA is cautiously optimistic that you will be approved by the national office without serious delay if we can settle on a time that works in your schedule.

Would you be interested in coming to Worcester to give this talk? If so, when if Feb. or March would you be able to come? The AIAA tends of meet on Wednesdays, in the evening, but an exception could be made. There are several groups our team has been working with that we feel would make good audiences for you. If you do not want us to mix a college student audience, a high school student audience and a teacher audience, we could arrange to have you meet them separately over the period of a day or two. The interested AIAA members would include professionals in the field as well as students and some educators in a mixed group, but the local non-AIAA audiences could be kept separate if you like.

If you were accepted as a distinguished speaker, AIAA would be able to cover your travel expenses. Please let us know what you think. Thank you for your time and attention.

Sincerely,

Patrick Nietupski, Nicholas Wheeler and Justin Linnehan

(pnietupski@wpi.edu)

P.S. WPI is on break from Dec 19- Jan 14. March 9-13 is also a WPI break. We also have to work around a break in the Worcester Public School schedule (Dec, 24 – Jan, 2) that comes before the WPI break.

## Appendix A.1.2

Kiker, Edward B Mr USASMDC
to Patrick

Classification: **UNCLASSIFIED**
Caveats: None

Patrick,

I would be greatly honored to participate in your effort. My generation is getting too old to go to the Moon and on to Mars, so it is doubly important to get the next generation leaning forward to make it happen. Right now my Jan and Feb calendars are open, so now is a good time to reserve time for a trip before something else gets scheduled. Do please be aware that if something comes up having to do with the immediate war I may have to reschedule, but I do not think it is likely. What dates look good to you?

I have been interested in space exploration since at least eighth grade. That year I got the top science grade in my class, and the prize selected for me was a book about the Moon as my teacher knew that was my biggest interest. I still have it. Over the next fifty-two years I have done a lot of work in lunar base planning, including everything from table-top models of entire bases and single buildings to full-size walk-in facilities of several rooms with active experiments on moon rock examination, hydroponic and lunar soil simulant gardening, remote control of robotic excavators, design of helium-3 gas miners, and much else. I gave the major presentation on lunar mining at the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space 1982 (Unispace '82) in Vienna, Austria. I worked with the Army Corps of Engineers Planetary Surface Systems Task Force designing lunar surface vehicles and operations, and with the International Lunar Base Design Conference at Beatenberg, Switzerland. I also worked with the Fusion Energy Symposium attendees at U of Wisconsin at Madison looking forward to mining the moon for helium-3 for clean fusion energy. I worked with landing site selection for Apollo 15 (Hadley Rille), and a classification system for the lunar rilles. Right now, aside form my Army missile defense work (I designed the operation and organization of our National Ballistic Missile Defense System and its Required Operational Capability), I am also working with NASA designing and building an innovative lunar surface radiation shelter to protect astronauts against solar mass ejections.

Attached are some ideas of efforts you might want to do in your city area. I have just started this list for you today, and will work on it to better flesh it out before I come. You will also be able to add to it. I expect you will be able to build it into a booklet on the topic that you can publish.

I am a member of the AIAA, and the Aerospace Technology Working Group (see HYPERLINK www.atwg.org www.atwg.org). My undergraduate degree was at Harvard in Lunar Geology.

<<Bio for Talks.doc>> <<BUILDING A SUCCESSFUL CITY SPACE PROGRAM.doc>>

SECURE THE HIGH GROUND!

*Ed*

Edward B. Kiker
General Engineer
Office of the Chief Scientist
US Army Space and Missile Defense Command/
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Classification: **UNCLASSIFIED**
Caveats: None

## Appendix A.2

Edward B. Kiker, SMDC/ARSTRAT Office of the Chief Scientist, Huntsville, Alabama

Mr. Kiker is the General Engineer for the Office of the Chief Scientist, US Army Space and Missile Defense Command/Army Forces Strategic Command in Huntsville, Alabama. He is responsible for searching out new technologies which can be applied to space to keep the United States the pre-imminent space power.

Ed attended Harvard University 1966-70, with major in Lunar Geology. He served four years on active duty as an Army Engineer Officer in Alaska, Korea, and Virginia, and for another four years in the Alaska Army National Guard as an Arctic Scouts Cavalry officer.

He performed LANDSAT satellite multi-spectral imagery work and environmental management in Alaska from 1975 to 1983. During 1981-87 he served as Alaska State Director, Project High Frontier, developing a notional National Ballistic Missile Defense System. He created and taught a college course entitled "Our Future in Space" at the University of Alaska. In 1982 Ed presented the Lunar Mining Program at the 2d United Nations Space Conference in Vienna, Austria.

In 1987 Ed moved to the Army Space Institute, Ft. Leavenworth, KS, where he developed the first Required Operational Capabilities Plan and the Organizational and Operational Plan for the National Ballistic Missile Defense System. He was also the Army Training and Doctrine Command Point of Contact for the Space Exploration Initiative during the administration of President George H. W. Bush. He represented the Army Corps of Engineers at the Second International Fusion Energy Conference, which recommended mining Lunar helium-three for fusion energy, and at the International Lunar Base Design Conferences in Beatenberg, Switzerland. He has worked with the Mars Exploration Office of the US Geological Survey and with NASA on Mars exploration, and located the best Earth analog site for the hematite concretions found by the Mars rovers Spirit and Opportunity. His major interests are enhancing Army space operational capabilities, mining the Moon for helium-three for clean fusion energy for the future, counter-terrorism, and exploring Mars for fossils.

Ed was with the Boy Scouts of America for thirty-one years, earned Eagle Scout rank, and served as Scoutmaster and Assistant District Commissioner. He is a Life Member of the National Space Society, a founding member of the Mars Society, and a Steering Group Member of the Aerospace Technology Working Group (see: www.atwg.org). He also works with the Federation of Galaxy Explorers, a national space-and-citizenship-oriented youth organization for children grades 3-11.

## Appendix A.3

# BUILDING A SUCCESSFUL STAR CITY SPACE PROGRAM

Edward B. Kiker
17 December 2008

The following items are not in any particular order, and may be accomplished by anyone with the desire to do them.

1. Contact the Federation of Galaxy Explorers (FoGE) at http://www.foge.org, and learn what they can do for you as a resource. Many lessons are downloadable from their website. Look at the requirements for becoming recognized as a Star City, accomplish them, and obtain the official designation "Star City." Work with the City Chamber of Commerce, local National Space Society and Mars Society chapters, Rotary, Kiwanis, Veterans organizations, and other city organizations to do this.

2. Some one person in the city must volunteer to be a central organizer or Coordinator for the Star City program. That person should have at least two back-up volunteers. The Star City Coordinator should be aware of and facilitate connections among all the space-related activities in the City, but is not in direct control of any of them. The Star City Coordinator must ensure that a Star City website is developed through which all space activities can interact. Such a website is normally hosted by a university, but can be hosted by anyone with the host capability such as a private business.

3. Start a chapter, or Mission Team" of the FoGE. FoGE is designed for students in third grade through eleventh grade, and each Mission Team is usually specific to one small age group. Each Mission Team must have an adult leader, and a sponsor organization that provides a meeting place. The Mission Team can then meet as often as it wants to organize and accomplish projects, then publicize its accomplishments on their Star City website. They can also develop new teaching lessons to submit to the FoGE website. Mission Team meetings often involve an invited speaker from the local area. In space subjects it is not just technology that is treated. Space also includes space art, space songs and music, space sculpture, and many other aspects of culture that space may impact. I have seen the most amazing space art mural created by about twenty students in a single meeting.

4. Assess what space activities are already going on in your city. Get links to all or most of them onto your Star City website. These activities will include businesses, university programs, grade school and high school programs, Cub Scout, Boy Scout, Explorer Scout, Girl Scout, Royal Ranger and other youth programs, planetariums, and any other space-related entities. Also include links to the Public Affairs offices of national organizations such as National Aeronautics and Space Administration (NASA), National Oceanographic and Atmospheric Administration (NOAA), Department of Defense, National Space Science

Technology Center (NSSTC), National Space Science Data Center (NSSDC), National Space Society and Mars Society and others.

5. Organize a listing of space-interested people's names, with their permission, with their specific interests, with email addresses and telephone numbers, across the city.

6. Organize a Science-Teacher-in-Service program which gets science teachers from across the city together monthly for invited presentations. This could be luncheon or evening programs, and might invite speakers from all branches of science from academia, business and government to talk on any aspect of science, not just space, as science teachers do want to keep abreast of developments in all aspects of science.

7. Encourage young people in the Scouting and other youth groups to complete the Space Exploration Merit Badge or its equivalent, and display to their Den, Troop, Post or other body what they have done.

8. Have a central place where student space accomplishments can be displayed. Also showcase these accomplishments at science fairs and a yearly Star City Space Show.

9. Encourage students to write to the Public Affairs offices of space businesses, NASA, NOAA, and foreign space offices for information. Do not forget Japan, Russia, China, South Korea, Canada, France, Italy, and even Switzerland. Many countries you might not think of as having space programs actually do have robust space programs even if they do not make space launches. These offices have free materials to send out.

10. Teach students to build models of space science objects such as lunar excavators, lunar and Mars bases, spacecraft, and other related things. Models are not toys. Models are engineering tools used to visualize what the end product is to be, and to fix problems early and cheaply before problems are made later and are much more expensive to fix. For example, a lunar base model should provide room to expand mines, workshops, and habitats. Moving everything over when new construction is needed is expensive. Models start with just a list of what is needed, such as power plant, habitat, roads, shops, and landing field. It then grows into drawings on paper or computer, then computer walk-through programs, then cardboard-and-hot-glue structures in a small scale, then perhaps full-size when the costs are sure and a location is secured. This is the same process by which automobiles, houses, aircraft, ships and manufacturing plants are designed. Ensure that models bear the names of the students who built them, and the advisors who assisted them. Signed work equates to pride in workmanship and a sense of ownership. Ensure students maintain notebooks with photos and written materials of what they have done. These records may well be very important in gaining admission to colleges and graduate schools.

11. Based on these models, have students build full-scale, functioning orbital, lunar or Mars facilities or equipment. These may include a habitat for sleeping, eating and recreation; a workshop for maintenance of lunar vehicles; an agricultural module for raising food plants, flowers, algae and fish; a waste digester to turn agricultural and kitchen waste to methane gas for energy; an outdoor lunar sculpture garden as if on the surface of the Moon; or a lunar tricycle or bicycle with carry baskets to force astronauts to get exercise while working and exploring outdoors in the light lunar gravity. The lunar tricycle or bicycle will become very important to the health of astronauts.

12. Have students identify what medical supplies should be on hand in a lunar clinic, and what medical knowledge must be available.

13. Have students identify what kinds of tools, spare parts and supplies must be on hand in a lunar maintenance facility. For instance, eye protection and hard hats are often needed. Duct tape is a vital part of a maintenance shop with hundreds of uses. Duct tape was needed to repair a lunar rover on the Apollo 17 mission. Kitty litter is wonderfully useful to get up dripping oil. These items are not silly, they are necessary. To identify what is needed, visit real shops, clinics, kitchens, and other facilities and ask the professionals there what they keep on hand. These equipment and parts lists are also a type of engineering model.

14. Have students identify the aspects of space in which they are most interested and personally meet adults who are already in this field either in person or by email. Have them identify, from these interchanges, the specific education courses they must accomplish in order to be considered for employment in that position.

15. Have students write articles for publication in the school newspaper, local newspapers, school anthologies of such articles, professional journals, and for presentation at local and national space conferences. It is important to get into the habit of publishing early and maintaining a file and list of personal publications. It is often difficult for a student to think of himself/herself as able to do such writing, but it is not at all hard to get published. Once a paper or article is published or accepted they become much easier. Ensure that the quality of composition, grammar and word usage are good. Provide illustrations if needed.

16. Have students produce space art, sculpture, songs and music for a public show in town, such as at a public museum, city square, City Hall, or space conference.

17. Have the students create and host a space conference with invited speakers.

18. Have students write short stories about space. Especially useful are stories in which the astronauts confront problems and figure out how to solve them. For instance, two astronauts are eighty miles from their base in a rover when the rover is struck and smashed by a small meteorite. Then their base tells them by radio

that a solar mass ejection has just happened and they must find cover from the radiation within thirty minutes. What do they do?

As you do some of these things, keep records of what worked and what did not work. Keep records of whom you contacted, and who gave the best information. Keep records of Internet websites that were useful. All of this will benefit others who later try the same or similar things.

# Appendix B

## Appendix B.1

For Immediate Release: News Release

Contact: Gina Maria Alimberti
(860) 623-3305
Email: gina-maria@neam.org

## New England Air Museum to Hold 2009 Space Expo on March 29

In collaboration with The Aldrich Astronomical Society and IGNITE , the New England Air Museum in Windsor Locks, Conn. will hold its annual SPACE EXPO at the Museum on Sunday, March 29. The theme of the event is **"Discover the Excitement of the New and Future Space Industry!"**

More than 15 exhibitors will participate in the event including the Connecticut Center for Advanced Technology, Talcott Mountain Science Center, Hamilton Sundstrand, Christa McAuliffe Planetarium, the National Oceanic & Atmospheric Administration (NOAA), Aldrich Astronomical Society and the CATO Rocketry Club.

Most of the activities will be hands-on. Visitors can try on a real space suit, observe solar flares through special telescopes, meet a NASA astronaut, pilot a space craft simulator, simulate the effect of weightlessness in space, handle rock and soil fragments from the Moon, measure the thrust of Estes rocket engines and much more.

The New England Air Museum is running the event with the help of Pratt & Whitney, Connecticut Center for Advanced Technology and Hamilton Sundstrand, a Division of United Technologies.

The Space Expo will run from 10 AM to 4:30 PM. For the convenience of visitors, a food vendor will be on hand all day. The New England Air Museum is located by Bradley International airport in Windsor Locks, Conn. For further information call the Museum at (860) 623-3305 or visit www.neam.org

## Appendix B.2

Presentations

10:15 Jim Zebrowski – *Galileo's Visions* – in honor of the International Year of Astronomy (45 minutes)

11:30 Astronaut Catherine G. "Cady" Coleman - After completing a variety of NASA missions including the Shuttle Missions STS-93 Columbia in July 1999 and STS-73 Columbia in October 1995 as a mission specialist, Cady is now preparing for a long-term mission to the International Space Station in 2010.

12:30 Mars Foundation – Bruce MacKenzie - *The Mars Homestead Project*
How to refine materials and construct a permanent base on the planet Mars

1:30 Astronaut Catherine G. "Cady" Coleman - After completing a variety of NASA missions including the Shuttle Missions STS-93 Columbia in July 1999 and STS-73 Columbia in October 1995 as a mission specialist, Cady is now preparing for a long-term mission to the International Space Station in 2010.

2:30 Worcester Polytechnic Institute Students Present their Research Projects:
*Mining the Moon for Tomorrow's Energy*
*The Case for a Moon Base*
*Advanced Ballistic Lunar Explorer*

4:00 Mars Society – Chris Carberry - *Why we should send humans to Mars*

## Appendix B.3

Exhibitors

Aldrich Astronomical Society: Handle rock soil fragments from the Moon as well as meteorites. Try out a space suit.

Arunah Hill Natural Science Center: Pictures and activities for the astronomer in all of us.

Astronaut Catherine “Cady” Coleman: Meet an astronaut who is preparing for long-term space flight in 2010.

CATO Rocketry Club: Ross Tracey engages audience in rocketry club activities.

CCAT: Try a rocket balloon launch and learn how rockets work.

Clay Center Observatory: Handle items related to astronomy and space science including a flown-in-space shuttle tire. Try out a Segway (helmet provided).

Copernican Observatory: Discover the physics behind space science.

CREC_NASA Explorer School: A NASA Aerospace Educator will lead the public in a straw rocket competition. Meet students who developed a microgravity experiment that was tested out by their teachers on a microgravity flight.

Discovery Museum: Rocket Science at its best.

FlisKits, Inc.: Original model rocket kits and accessories, with a focus on beginner rocketry and education, available for sale.

JPL Solar System Ambassador – Bruce Irving: Try out a simulated shuttle launch, moon landing, or solar system tour.

Hamilton Sundstrand/Lockheed Martin: Learn about the aerospace industry today and what it offers our future.

Mars Foundation: See how to build a house on Mars.

Mars Society: Learn why we need to take man to Mars.

McAuliffe-Shepard Discovery Center: Learn about the atmosphere of Mars. See a tornado form before your very eyes.

NOAA: Information and demonstrations having to do with weather and preparedness.

Talcott Mountain Science Center: Make a sundial. View the photosphere and the chromosphere of the Sun.

# Appendix C

EHANA Scenarios for Lincoln Square

**EHANA Team Vision for Lincoln Square (most notably the auditorium)**
Matthew Phillips, Tyler Flaherty, Hubbard Hoyt

Our vision for the auditorium of Lincoln Square is to use it as a place for college students to connect and we feel that the best way to achieve this is to use it as an academic hub for students in Worcester. We believe that there should be a social scene in the vicinity but in order for students to connect and get to know each other, we feel the best way is to get them in classrooms together. With appropriate transportation most, if not all of the colleges in the consortium should be able to get their students to the auditorium to participate in classes not offered at each individual school. With a common education it is our belief that students from the other colleges would be more inclined to interact rather than turning Lincoln square into an area full of students from different schools with no common interests. We have several ideas for classes that could be offered at the auditorium and we will outline them below. Another idea to incorporate into the plans is to also involve high school students in several events hosted by the auditorium because it would make students aware of their choices for higher education in the area and perhaps give them more of an incentive to stay here for college rather than to move on elsewhere.

In our meetings with our advisor from WPI we have come up with three possible class ideas:

**A**: Political science primarily focusing on the property rights in space: This idea came up because we feel that it would draw an interest from other schools as well as appeal to students at WPI. The idea of farming and building bases on the moon has been discussed for a long time and we feel a class that focuses on the technology involved as well as the societal issues would be a beneficial and interesting class for all kinds of people.

**B:** A woman's study class: The reason for this idea stemmed from the fact that WPI has a much lower female population than male and by opening up such a class to other students of the consortium colleges a large participation for such a class would not be unreasonable.

**C:** Urban studies program: There are several other colleges that offer urban studies programs and we feel it would be a good idea to bring all the students together into one place. Admittedly you can take classes at any college in the consortium but bringing the class to one common place that is not owned by anyone college would be beneficial to the idea of bringing student life to Lincoln square.

As well as these classes it is our belief that the students of Worcester should have a joint college government organization that could help decide on future events in the auditorium and to host its office here would make perfect sense. As stated at the beginning, it should not primarily be an academic zone but we feel that it is the first step in bringing students together as one group, a group that represents Worcester as a whole and not any individual college.

**Quincy Market Vision**

Large retail outlet chains have swept the American landscape in the last century, especially since 1950. As time has gone on, fewer small local shops have been able to compete and those that can rarely compete for prime locations and last for long. Especially in large cities, small shops that give the city flavor are hidden among the chains stores and fast food outlets. In Worcester family businesses held on longer than most places, even in the large food stores, but now the Iandolis are gone and Price Chopper and Stop and Shop have taken over. Many smaller establishments and specialty shops have failed, but some still exist and there are even some recent startups. That's why it's fitting that the Worcester Auditorium becomes a gathering of small craft and specialty outlets in prime space surrounding a space that features varied live entertainment. This would be one step better than the crowded Quincy Market with floor space so expensive that there is not room for entertainment and displays in the center of the buildings and certainly no massive stage that could be devoted to it.

Many towns and cities still hold outdoor markets, some more permanent such as Quincy Market, others lasting only a day and operating out of doors. Our goal would be to make the atmosphere of the outdoor market semi permanent inside this massive public building. There would be a changing cast of characters the average one setting up for a month, but others there for a season and still others coming and going in a week.

The slow pace and relax shopping experience with local dealers is what makes it a unique and popular experience. All age groups are satisfied with actives such as jugglers and magicians and with the shops from candy shops to blown glass shops. The Auditorium has a unique floor plan that makes the indoor market a practical idea. With a large footprint and high ceilings, it gives a more open feeling. This would allow for small semi-permanent stands to be dotted around the edge of the Auditorium with the center used for musicians, demonstrations, political gatherings, informational displays and and other entertainment. People could walk around the small retail shops mixed with local craft shops that express the diversity of Worcester. During warmer months it would spread outdoors along the streets and green space in front that would give Worcester a livelier feel.

In particular, we think ethnic groups with different holidays should be encouraged to take over the center stage and be given a large proportion of the stalls and retail space surrounding the hall at specified times of the year.

Yes, the Auditorium should pay for itself, but it should also be a splash of color, local color, in Worcester, that changes like a kaleidoscope a bit at a time, but in the end is in constant flux and transforms from one form to another.

**Worcester Memorial Auditorium:**

Culturally Diverse Local Arts and Performance Center

A vision based on recommendations by Nathaniel Needle, Ed.D.

This proposal is roughly based on an arts center built in the town of Middletown by Wesleyan University. Called the Green Street Arts Center, it was opened in 2005 through collaboration between the university and the city. It hosts a number of art-related activities and events for people of all ages. It now serves as a vibrant cultural and educational center, combining the resources of Wesleyan and Middletown.

Unlike the Green Street Arts Center, the scale of the Auditorium will clearly require political commitments at the state and federal level for restoration, based on its status as a major historical war memorial with unique and irreplaceable philosophical and

architectural/artistic elements. That political effort, of course, will be aided by a broad consensus on how the facility will sustain itself as well as the cultural life of the community, once it is restored.

No single Worcester College should be expected to take on the role that Wesleyan takes on in Middletown. To the extent that Middletown is a "college town", it is so only because of Wesleyan. Worcester, by contrast, is blessed with a network of institutions that could play a collaborative role in programming, using the whole institution as an incubator for supervised hands-on student practica in fields ranging from engineering to history to the arts to education, and more.

While allowing time for student use gives the Universities the reason to develop the auditorium it should be used on it's off time as an arts and cultural center. Worcester has its fair share of arts, crafts and cultural diversity and using a building as prestigious as the auditorium would make for a perfect setting to bring this out. Local arts and crafts vendors would have a great opportunity to sell their unique stuff and cultural events could also take place here. It is to historical of a building to go to waste as a commercial center and would be most fittingly renovated as somewhere to enjoy the crafts and culture that Worcester has to offer.

**The Main Floor of the Auditorium (peace studies vision)**

The Goddard Memorial Moon Base was given only one small room on the main floor of the Auditorium to serve as a small museum display devoted to rockets and the inventor honored by the Moon Base below. The main floor is shared by a variety of groups and is both a crossroads for the 20,000-30,000 college students of Worcester and a facility that is run by the Veterans of Foreign Wars and the Intercollegiate Peace Studies program of the COWC. These two groups, one conservative and the other liberal, both agree that this is first and foremost a War Memorial and should be devoted to honoring the millions that died during World Wars I and II by keeping the Peace.

What they want to do is spend half of their time looking backward to remember those evil days. They also want to look forward to try to prevent another World War and nuclear wars of all kinds. The college crossroads part of the mission is that the main floor of the Auditorium is a bus station and gathering place. Buses arrive from every college in Worcester on the half hour so a student can go from one college to another in a short time by changing busses at the Auditorium.

However, students from all over the city can also rapidly gather at this site for a meeting, event or a class. There is also a restaurant in the building as well as a small theater for people who are waiting around for things to happen or between events. Busses also go from the Auditorium to the train station, several malls and Shrewsbury street from this location, but it is really Highland Street and North Main, easy walking distance from the crossroads, that is emerging as the college town strip of Worcester.

The job of the Peace Studies dept. is to run consciousness raising events about threats to the Peace and encourage diplomacy and negotiation as the way to manage international conflict. It all came about because the college students of Worcester gave a present to the City in the form of a restored and renovated Auditorium and the city in return asked the students how

they would like to see it used? The college crossroads and the peace studies department was their answer.

Peace studies has made a reputation for itself in the region by developing model UN events and role playing games that feature international diplomacy about global issues ranging from the Nuclear Proliferation and Global Warming to the Asteroid threat to World Civilization and Global Inequality. They try to concentrate on the World Peace issues, such as the threat of Weapons of Mass Destruction.
Teams from the colleges play the Model UN style games first, and those that look promising are run for the HS students after they are revised to fit the Social Studies curriculum.

The continuing cooperation between the social studies and science departments of the Worcester Public Schools and the college social science and history departments has been a good thing, as expected. What no one expected was the flourishing group of science fiction writers pouring out of the English departments of colleges in Worcester writing popular novels and plays and movie scripts. The special effects departments of the local college theater groups are getting quite impressive and alumni often bring new works to Worcester to try out in a class or on the stage. The best college play in Worcester is almost certainly going to play in a downtown theater and the best high school play in the region will play the Auditorium for a general audience with lots of college student audience.
In fact, the auditorium is now a multimedia entertainment center and for a few months of the year it is set up for school tours in which people can emerge out of part of the cellar area through the facilities under the stage and it is like they came up out of bunkers built for trench warfare on the Western Front of WWI at the Somme or Verdun. One year it was like coming out of a London Bomb Shelter into the "Blitz". You always see a visual image of what you would have seen on a famous battle field projected onto several screens on the first floor. The images are powerful and getting more and more professional and thus are drawing a wider audience. The high school social studies class tour audiences are about half of the viewers of these displays and the plays that use the display as a set are drawing wider and wider audiences. Work is underway to create more famous WW II images simulating not only London but Stalingrad, Bastogne, Guadalcanal, Dresden and Hiroshima. Several peace conferences are considering holding their annual meetings and political organizing meetings in Worcester due to the draw of these exhibits.

## The Simulated Moon Base as a Cooperative Education Project

It was when I visited Lincoln square in 2012 that I first caught a glimpse of this new future. By then the students of WPI, Clark and RISD (RISD students designed the Lunar Lander for NASA) had finished building a proposed mockup of what the Lunar base would look like.

It was set up "temporarily" 2010-2020 in the basement of the Worcester Auditorium- though as the building was renovated and got busy again they planned to move the simulated Moon Base to the old tunnel that went under Lincoln square, connected by a tunnel to the Auditorium basement.

I went with a group of 8$^{th}$ grade students on the "Goddard-Kennedy moon base" tour with a college student tour guide. A Clark student named Jennifer welcomed them to "a space station orbiting the Moon". Soon we were loaded into a mockup of the RISD Lunar Lander (built into a

freight elevator) and told to "suit up" properly for the airless, one 6th Earth gravity into which they would soon be arriving. Jennifer had told them that the Moon was going to be as important to Earth economy in the 22nd century as the Persian Gulf is in the 21st.

The group and I went down two floors and stepped out into a panoramic view of what the surface of the Moon would look like at the South Pole. We were told that cosmic rays require that the habitat part of the base must be buried deep underground. We transferred from the "lander "to the pressurized tunnel car that takes you on a visual tour of the underground moon base. During this time we are going though a side lit greenhouse illuminated by solar energy. Our guide told us we could not breath that air as it was optimized for plants that like a lot of CO2. The animal optimized atmosphere was the next stop.

The college students tending the plants in the greenhouse all wore protective suits with oxygen systems to breathe in a place where vegetables grew twice as big and twice as fast. Then we passed into the human habitat. We were told that the oxygen in this area was produced from the plants we had seen and the plants made oxygen from the CO2 in the human habitat. There were several interesting exchanges going on between the plant and animal units such that nothing was wasted. The 8th graders learned that there were some animals in with the plants, earthworms mostly, but that the "farmers" mostly kept track of the microorganism world in the plant unit. Potential plant diseases and nitrogen fixing bacteria were the key to managing a plant habitat.

I was really impressed with the unexpected ecology/biology lesson, and the illusion was complete. We were in a moon base designed for 30-50 people complete with underground agricultural unit designed by students at WPI in 2008 and built by some of the college and high school students in 2009-2010. Our tour guide let us look through a window at 6 students who volunteered to live in this unit. They were part of a study by the Biology Dept at Holy Cross, the Psychology Dept at Clark U and the U Mass. Medical School on the effects of isolation and stimulus deprivation funded by NASA. We could peek in at them, but they could not see us. The other 4 WPI students were the people who "delivered" tools and supplies to them for their work-their only "in person" links to the outside world and they showed up only once a month.
The 8th graders had all kinds of questions about how long you stayed and what one 6th gravity felt like. The tour guide seemed ready for such questions and had a variety of visual examples such as the one that simulated being in 1/6th gravity. An hour had flown by and soon the teacher was dragging them toward the exit staircase back up one level to where their bus was waiting.

Our tour guide said that she knew all their questions had not been answered but if their class in school wanted to stay involved they could set themselves up as another science base at another point of the moon, or in a space station and communicate with the students living in or running the Space base. In particular, the Interdisciplinary Space Studies Majors of the Worcester Consortium were looking for "the other 90%" of the lunar work force. She explained that in a lunar factory taking advantage of the near vacuum conditions for production only about 10% of the work force would be on the Moon. The other 90% would be on Earth manipulating semi autonomous robots via radio control with instructions. Enough problems were anticipated that 10% of the "workers" would be on the moon at any given time, but most of the time, you would be able to live in Worcester and be employed by Luna-Corp as a factory worker

Once they were "part of the lunar economy" they could ask questions of any of the 3000 other people in the network. As a "sister" site, they would be given a job to figure out how to do and put in Email communication with Goddard Base in Worcester. Then the COWC students in Worcester would be accessible to them and answer all their questions about science, work and life on the Moon. The teacher asked if a WPI or Clark student would be sent to Fitchburg to help him

get set up to do that. He was assured that that was possible but that he could also recruit some Fitchburg State students to come to Worcester for lunar production training in a special evening course set up at Worcester State College for the purpose.

**The Business Incubator**

As a result of all this ferment, Worcester was way ahead of the game in moving into the emerging space economy. Several college alumni started new businesses designed to bring down the cost of access to space or travel in space. The most famous of these was Paul Klinkman (WPI Class of 1976) who invented an in orbit refueling system. This innovative satellite system gathered most of the gases necessary to make rocket fuel locally in Low Earth Orbit so they did not have to be lifted from Earth. It is estimated that this system will be worth $2 billion to NASA on just the 20 planned trip to the trips to the Moon (2 per year from 2020-2030), in which the Moon base will be built. There is no question that the invention allowed mission planners to take two and a half times as much weight of equipment to the moon to build the base on those 20 missions.

Klinkman decided to set up his business in Worcester, so as to be near WPI and employ its student's part time. He was short of cash, but there were unoccupied buildings in Lincoln Square in 2008. So, he offered to renovate part of one of them if he could have the space for 5 years tax free and rent free. (Three other start up firms offered to renovate the rest of the building under the same terms.) The city took the deal, and now two of those companies have major new facilities built in Worcester. One of the others is renovating some city owned space in a large old factory. The last went bankrupt.

The Boys and Girls Club building renovated by those 4 startups is now the home of the new Worcester Consortium of Colleges IIISS program, (Intercollegiate, Interdisciplinary and Integrated Space Studies). This college major is world famous. Students can take the major by being accepted into any one of the colleges in Worcester. The Worcester High School students that went to Worcester State College to study business and economics have created a powerhouse program leading to non-technical careers in the aerospace industry. The emerging space hotel and tourism industries are the special strength of a similar program at QCC.

Aerospace engineers are pouring out of WPI into a field that lost 25% of its manpower due to retirements from 2007-2012 and needed a massive infusion of talent into a starving job market. The space science effort grounded in biology and focused on life support is centered at Holy Cross in collaboration with the U Mass Medical School. Clark University, where Goddard taught, is emerging as a major center for lunar geology, geography, chemistry and the psychology of living and working in space. The College of Pharmacy is collaborating with NASA to take advantage of the fact that a micro gravity environment speeds up the production of cultures of certain types of medicine. Whether the same will happen in the $1/6^{th}$ gravity of the Moon is now of interest to NASA. Space has an impact on the human body similar to an accelerated aging process. Biotech firms in Worcester under contract to NASA are working hard on medicines that would counteract that effect. Estimates of the spin-off impact of this work on mitigating the effects of aging on the general population are optimistic. Privately, some insiders say that this field is going to be a goldmine given the aging US population and the edge that the space contracts have given Worcester over competing biotechnology and medical centers.