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Lunar Development Robotics Competition

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LUNAR DEVELOPMENT ROBOTICS COMPETITION:
Creating a New Generation of Hybrid Space Technologists

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by

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Abstract

This project focused on championing the idea of a college-level lunar-themed robotics competition. Returning to the Moon and creating livable lunar bases there, as well as the associated issues with doing that, are going to be persistent problems in the upcoming decades. A large problem will be determining how to handle lunar regolith and use it as a resource. Semi-autonomous robotic systems seem to be the most promising way of doing this, as they have low risk and an acceptable cost. Using this and other future lunar development problems as a theme, we proposed that a competition be developed that would help draw interested college students into this emerging interdisciplinary field of hybrid Space Technologists, beginning with robotics and the Moon. College students might see it as an exciting way to gain valuable practical experience with robotics and lunar environments, as well as display their skills to potential employers interested in robotics and space technology. We believe that this competition would help to create a new type of hybrid engineer who will be capable of dealing with the lunar problems that will become prevalent in the next phase of space exploration.

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Executive Summary

Our Interactive Qualifying Project involved designing a college student competition that would meet the needs of both the Aerospace and Robotics Engineering fields. The name of this proposed competition is the Lunar Development Robotics Competition (LDRC).

The growing field of Robotics Engineering has benefited by providing extracurricular ways for students to gain an interest in or explore an already existing interest in robotics. There are several existing robotics competitions, one of the largest and most popular being the FIRST competition. The main competition that FIRST sponsors is the FIRST Robotics Competition (FRC) for high school students, although they also sponsor two other competitions (FIRST Tech Challenge and FIRST Lego League). Members of the FIRST Community, as well as others involved in robotics, are looking for potential follow-on robotics competitions suitable for college students. NASA has sponsored a few robotics competitions as well, but they were not annual events and more often NASA sponsors design competitions with Aerospace applications, such as Revolutionary Aerospace Systems Concepts Academic Linkage (RASC-AL) or the Centennial Challenges. One of the seven Centennial Challenges that NASA currently sponsors, the Lunar Regolith Excavation Challenge, does provide an especially interesting model for an annual college competition.

The Aerospace Engineering field is in a period of transition. One of the next major goals is colonizing extraterrestrial bodies in space, starting with the Moon. Building sustainable space bases requires a much more diverse range of expertise than was previously required in past aerospace undertakings. Building a lunar base out of largely local raw materials will require the participation of disciplines that weren't traditionally considered to be a part of aerospace. All these varied, non-traditional disciplines need to be able to work together, acquire new interdisciplinary skills, and become more aware of the space environment in order for a space base and later colonization to happen. Team level competition has proven popular in the field of robotics, and could generate the required interest and knowledge of the space environment among students studying these desired disciplines.

In order to insure we designed an appropriate competition, the following objectives were established at the beginning of the project:

- Determine if both fields mentioned above, Robotics and Aerospace Engineering, would be equally well served by a single competition.

- Champion the college-level lunar-themed robotics competition idea and assess the response by colleges with majors in or related to Robotics and Aerospace Engineering.
- Determine if potential sponsoring aerospace organizations, such as NASA and the AIAA, would be willing to work with the robotics community to sponsor our proposed competition and provide financial, promotional, logistical, and other resources designed to draw in people and organizations with robotics aspirations or expertise.

The project began with a series of meetings to discuss the details of the proposed competition to the point that it could be presented effectively to people from whom we wished to get a response. Once a working draft was developed, we presented it at the AIAA YPSE (Young Professional, Student and Education) Region I Conference in Laurel, Maryland on November 21st and 22nd of 2008. We were able to champion our idea to many AIAA Region I members, including various leaders in attendance at the Regional Advisory Council (RAC) meeting. Mr. John Malay, the Director of AIAA Region I, seemed to find the idea especially interesting. We were also able to discuss our idea with Mr. Andrew Petro, a Program Executive in the Innovation Incubator and Centennial Challenges Office at NASA, who attended the Conference at our suggestion, primarily to hear our proposal. The benefits of presenting at the AIAA YPSE Conference were twofold: we were able to champion our idea to potential sponsors in the AIAA and NASA, and we gained valuable feedback to further refine our idea of what the competition should look like. It later became necessary to express the idea in summary form as part of the cover letter for a questionnaire, which was to be sent to nearly one hundred university based organizations associated with the FIRST competition network. In this format we would no longer have the luxury of having half an hour to develop the idea in person and to answer questions.

One of our advisors continued discussing our idea with Mr. Malay and Mr. Petro, and we broadened our discussion to include more of the WPI faculty and students (the Aerospace and Robotics Engineering faculty, the WPI student chapter of the AIAA, and the New England Chapter of the AIAA). WPI also participated in a conversation with several universities that entered in NASA's Lunar Regolith Excavation Challenge, the inspiration for our Lunar Development Robotics Competition idea, as well as the California Space Authority (CSA) which was selected to run it. It became evident that the universities were not happy with the way the NASA Lunar Regolith Excavation Challenge was being run and several of them wanted to take it over. Our ideas for how to make it more student friendly became involved in the discussion, as did the idea that it should be a continuing event catering to college students. So NASA's event that was the inspiration for our college student only Lunar Development Robotics Competition (LDRC) idea started to change in the direction we had laid out for LDRC.

Overall the response from WPI about co-sponsoring and hosting a lunar-themed robotics competition was not unanimous. The robotics people were more interested than the aerospace people, and even the robotics program staff was divided about what the best kind of robotics competition to host would be. An alternative, non-lunar concept had been proposed to the National Science Foundation that was funded, so that would be attempted by WPI first in any case. So, if NASA and the AIAA endorse the idea, it is just as likely that a consortium of colleges with WPI as one member would host the competition as it is that WPI would take it over as a continuing annual event on campus. However, if a lunar test bed could be set up in the Worcester area, it would increase the odds that WPI would decide that the benefits of hosting a lunar themed robotics competition, such as ours, on a continuing basis were worth the costs involved.

Several AIAA Region I leaders, on the other hand, seemed very excited about the idea, but felt that the national office should handle something on this scale. One of the leaders showed us how to identify other student competition programs sponsored by the AIAA on the national website. Mr. Malay mentioned that he would endorse the idea and bring it up at the next AIAA National leaders meeting, since it should be more than just a local event.

Most AIAA National council members agreed that it was an interesting idea that had potential, but they were reluctant to commit AIAA resources and sponsorship to it for the coming year before they had more information about NASA's policy focus for the next five to ten years. Some of them thought that the plans to return to the Moon would be abandoned. Mr. Petro was intrigued by our ideas, but seemed reluctant to reallocate resources away from the Centennial Challenges NASA was already sponsoring to do something strictly for the college population. He seemed very interested in finding some way of incorporating college friendly concepts into NASA's Lunar Regolith Excavation Challenge, which he expected to be run every five years.

This left us with a fairly good idea what the AIAA and NASA liked and disliked about our proposal. It also gave us some indication of their level of interest. However, the lingering question seemed to be that if it were held, would it attract a lot of participants? Since we hadn't yet approached members of the robotics community, aside from our own robotics faculty, it was not possible to answer that question without some serious research. We needed to get some feedback from potential participants in our competition, both college students and their would-be coaches. Thus, we designed a survey instrument using SurveyMonkey.com (included in Appendix B) to send to colleges and universities involved in mentoring FIRST robotics teams. This survey has not yet been sent, but it has been through the IRB Review process and received an exemption (the exemption letter is included in Appendix C).

Based on the feedback we have already received, we have established the following concepts as our competition idea:

- College-level robotics competition to solve lunar based problems (Lunar Development Robotics Competition or LDRC)
- Interdisciplinary or multidisciplinary teams of college students with varying majors
- Progressive themes
    - A new goal each year building upon previous year's goals
    - A single theme, such as lunar robotics, to be run five to ten years, at which point it will be replaced by another five to ten year progressive theme
        - Note: NASA is aiming to have a lunar base by 2020
        - We will be done with one round of competitions by then and will have produced a batch of hybrid space technologists ready to deal with the interdisciplinary challenges that will come with building that lunar base
    - Each theme will be in the field of space and/or robotics and will focus on practical solutions to current realistic problems, as opposed to the game-like atmosphere of other educational competitions
- At least top three designs will be required to be open source, open schematics, etc.
    - Allows future participants to build off of successful solutions to previous problems
    - Allows competition goals to increase in complexity without increasing much in difficulty
    - Discourages companies who would want to develop trade secrets (companies can still mentor or coach a team)
    - Encourages an academic, open learning atmosphere that is beneficial to a student competition
- Entrance fee of $3,000
- Small cash prize
    - $50,000
    - Could be called Goddard Prize in honor of the WPI graduate who most distinguished himself in the field of aerospace and rocketry
- Schedule to fit college student's needs
    - Enough advanced notice of the goal so they can pull together the required team and work on the problem, ideally for academic credit if their institution allows it
    - Possible schedules (to be chosen based off of survey results)

        - Competition announced over the summer and held during winter semester of the school year to benefit/accommodate students who are doing it for credit
        - Competition announced during winter or summer and held during summer or winter break so students won't miss class time to compete
- Competition to be held at a college or a lunar test bed, such as the one used for the NASA Lunar Regolith Excavation Challenge
- Hopefully sponsored by AIAA, NASA, and/or FIRST, with the National Space Society as another possibility
    - Ideally with
        - FIRST providing the manpower and some judges with robotics expertise
        - AIAA providing logistical support, advertising, and some judges with aerospace expertise
        - NASA providing prize money
        - A college hosting the competition, providing a location and some staff

There is still much to be done in order to make this competition idea a reality. We recommend that another IQP team be formed to act for WPI and work out the remaining details, especially negotiating with the AIAA. They should also maintain contact with AIAA and NASA, send out the survey instrument, and keep tabs on the NASA Lunar Regolith Excavation Challenge.

Background Information

The idea behind our IQP arose out of two distinct and separate problems. The first problem lies within the field of Robotics Engineering. There is a desire amongst people in the robotics community for the creation of a college-level robotics competition that will give students a way to further their involvement in and experience with Robotics Engineering. However, competition holders are reluctant to move resources from their current competitions in order to start new ones. The second problem lies within the field of Aerospace Engineering. The goals and interests of the aerospace community are changing and shifting from traditional Earth based aeronautics to space exploration and colonization. The aerospace field is going to need a new type of engineer if they are going to facilitate this change in focus without holding back technology. We believe that our IQP can help to solve both of these problems. Our idea is to create a college-level lunar-based robotics competition that is based on the problem of excavating and transporting lunar regolith so that it can be processed for resources or used for construction purposes. This idea addresses the desire of the robotics community to have a robotics competition aimed at college students, and it also has the potential to create the type of hybrid, aerospace minded robotics engineer that the aerospace field is going to need in the future.

Robotics Competitions

With the increasing popularity of robotics as a hobby and a field of academics came the creation of robotics competitions in which contestants design and create a robot to fulfill a specific goal laid out by the competition designers. One of the most popular of these competitions is the FIRST Robotics Competition, which is aimed at high-school student teams that usually have a university or external corporation sponsoring and helping them. FIRST also hosts two other competitions, the First Lego League (FLL) which is for students aged 9-14 and the FIRST Tech Challenge (FTC) which is a lower cost alternative for high school students. The FIRST competition has been very successful with high school students who have an interest in robotics, and has been instrumental in increasing the popularity of robotics as a whole. No other technical field has so stimulating an opportunity for young people to experience, not even aerospace, which has a tradition of model rocket clubs and competitions. However, the FIRST competition has left high school students wondering what will come next, once they reach college. Traditionally, FIRST veterans tend to help out other high school teams as mentors, but if they

wish to continue to be contestants, there are a number of robotics competitions available, hosted by a range of companies and organizations (the NASA Lunar Regolith Excavation Challenge for example). These competitions, however, are usually aimed at drawing in startup companies and organizations with larger budgets than universities and are typically designed to produce some kind of usable technology (Unmanned ground and aerial vehicles, etc.). College-level student teams can enter and have been successful in these competitions before, but they are forced to compete against organizations with more resources, different schedules, and fewer constraints than they have. A competition that is designed so that college students can easily form teams and participate would be a way for students to continue their involvement in robotics from high school, and gain more experience in the field. For these reasons, the desire for a college-level competition is already present in much of the robotics community. However, the organization that already hosts the FIRST competitions is reluctant to diverge from their current competitions in order to organize a new college-level competition. The need and desire for a college-level competition is still present in the robotics community, because the niche that FIRST created is not being fulfilled by an extension of that organization. FIRST is conflicted, wanting its veterans to stay involved by coaching high school teams, but the development of the field requires those students to move on and tackle larger practical application challenges. Some organizations seem eager to step forward and host a college-level competition, but the typical approach is to get a grant and run the competition only once. What is needed is a sustainable network like FIRST to emerge. Hence our concept of how to get an annual event started is with a sponsor that has a continuing interest and evolving agenda.

The Changing Field of Aerospace

The entire aerospace field is about to undergo a change, as roughly twenty-five to thirty percent of the current population of aerospace professionals will be eligible to retire in the next five years. At the same time, NASA is shifting its attention to returning astronauts to the Moon and figuring out how to develop a sustainable base there. They are investigating things such as lunar bases, regolith (lunar soil containing many valuable resources) processing, and lunar excavation. In order to accommodate the changing American goals of the economic development of near space, the aerospace field is going to have to be repopulated with a new type of hybrid aerospace engineer that has an interdisciplinary background and is capable of working with and understanding teams of people from different fields of study. These hybrid engineers will have to work in teams with professionals from traditional technical fields such as Electrical Engineering, Computer Science, Mechanical Engineering, Civil Engineering, and Physics, but

also with professionals from fields such as Business and Psychology who will be involved with developing a new trade system and human habitat. They will also have to have an understanding of the space environment, and what kinds of challenges are presented when engineering is done in a non-Earth setting. These types of engineers will be instrumental in advancing the field of aerospace, but they are going to have to start getting involved while they are in college.

We believe that our IQP idea can serve as a solution to both of the problems listed above. By developing the idea of a college-level robotics competition and championing it to different organizations, we can fulfill the desire of the robotics community to see a robotics competition involving practical problems up and running. This competition will draw in adventurous and innovative college student teams and give them more practical experience. By making that competition centered on lunar technology and regolith processing (the same goals that are present in the NASA Lunar Regolith Excavation Challenge), we are also helping to foster the new generation of aerospace engineers that will have to be more interdisciplinary to keep up with the goals of the changing industry. A lunar-based college-level robotics competition will serve as a place where students can interact with students from other majors, and get the experience they need in working with teams and understanding the needs and issues of other fields of study. Overall, our competition idea will solve some problems for both the robotics and aerospace communities, as well as provide interested college students with a place to demonstrate their skills and abilities to a variety of potential employers.

Statement of Objectives

Our project set out to accomplish several different objectives. The first objective was to determine whether or not both of the problems mentioned in the Background Information Section above could be solved with a single competition. Once that was determined, our second objective became championing the lunar-themed robotics competition idea by showing people why it would be beneficial to both the robotics and aerospace communities, and getting reactions to the case we were making. Lastly, once we had gotten this proposal under discussion, our final objective was to find out whether or not key potential sponsoring organizations such as NASA and the AIAA would be willing to provide financial and other resources to the robotics community so that a college like WPI could run the proposed competition on their behalf. These objectives were all questions that we wanted to find the answer to before the end of our project, which is to be completed in May 2009.

Our first objective was to determine if the competition concepts satisfied the needs of both the robotics and aerospace communities that were detailed in the Background Information Section. For the robotics community, our competition had to provide an annual arena for college students to demonstrate their skills and maintain their interest in robotics after graduating from high school. It also had to be a college student friendly competition, meaning that the participation costs would be minimal and the competition would take place in a student friendly timeline. A student friendly timeline would be one that allows for planning courses and projects around the competition toward the end of the academic year, so that students can get academic credit for participation in the competition. For the aerospace community, our competition had to provide a way for students to interact with students from other majors, learn more about the space environment, and become more interdisciplinary. This way, it would help to foster the new generation of hybrid aerospace engineers that will be needed in future lunar-oriented space endeavors. By making the competition focused on lunar regolith excavating technology, and having it take place during a time when students could actively prepare and participate in it, we believe that the proposed lunar-themed robotics competition would satisfy enough of the needs of both communities to be worthy of continued support.

After the competition idea was formulated and agreed upon, our second objective became championing our idea to various robotics and aerospace organizations and trying to convince them that our competition was worth supporting as a viable solution to some of their problems. Two important organizations that we decided to focus on were the American Institute of Aeronautics and Astronautics (AIAA) and the National Aeronautics and Space Administration (NASA). Having the proposal reviewed

by key members of these organizations and having them provide us with feedback was a major step forward in the process of getting our idea some visibility and endorsement. Having contacts within AIAA and NASA also provided us with a convenient avenue to bring the idea to the attention of universities with AIAA student chapters and other student organizations that could distribute information and form teams.

NASA was of particular interest to us because their already established Lunar Regolith Excavation Challenge was a model which served as a source of ideas for us regarding our own lunar-themed competition. We knew that this area of activity was of interest to NASA because they had singled it out for one of their Centennial Challenges. The Regolith Excavation Challenge also provided us with a way to get ourselves in touch with NASA, because it gave us a way to locate the right person to review our idea. The AIAA was also of interest to us because they have a history of sponsoring aerospace themed student design competitions. These previous events told us that they had experience with sponsoring and running successful student competitions and contests with college students as the sole participants. Getting feedback from these two organizations about our idea was an essential part of making our proposal more robust.

Once we had begun to champion our idea and make organizations in the robotics and aerospace communities aware of it, our final objective became to determine how willing the organizations would be to provide the resources needed to make our competition idea a reality. If we could convince both the AIAA and NASA that our idea would be a great help to both the robotics and aerospace communities and get them to provide money and sponsorship, then we would have a much greater chance of convincing WPI to host the event, thus getting it off the ground. Since this would be a competition designed for college students, we knew that the prize money offered by the competition would be relatively modest compared to other robotics competitions. We also knew that NASA had a relatively large budget set aside specifically for funding research competitions. Hence, we figured that NASA would be more likely to front the prize money for a competition such as ours if it was compatible with, and more promising than, their current competition. Also, because our competition was centered on space technology and the lunar environment, the AIAA seemed to be the perfect sponsor for such a competition. They have an extensive \ network of student chapters in universities around the country, and would easily be able to spark interest and motivate some potential participants. The potential for assistance from the AIAA and NASA was great in that the proposed competition was a good fit with their organizational missions, but we had to determine how much of what we were asking for was actually feasible.

If we could gather enough information to answer all of the questions listed above, then we would know whether or not our idea for a lunar-themed college student robotics competition was a realistic idea for the immediate future. If we learned that the organizations we talked to weren't interested in our idea right now, it could prove to be a potential problem since someone will develop a college level robotics competition to follow FIRST sometime soon. However, not acting immediately is not necessarily fatal to the idea, and the process of deliberation needs to start somewhere. There should be room for about three competitions, one designed to be a sports contest with no practical goals, one designed with an emphasis on practical and immediately useful devices, and one designed with an exciting and exotic flare to open up a future new avenue of development. We wanted that third role to be associated with the WPI robotics program, so the other niches could be filled and still have our proposal make sense. However, the more competitions there are, the more diluted the pool of competitors in each one becomes. So to take on the role that FIRST has at the high school level, one would have to act soon, but a more limited role as a regional contest or as a niche with a major sponsor akin to that which has developed in the underwater robotics sphere could probably still be carved out anytime in the next 5 years. After that someone will probably engage the FIRST network to create a more advanced level competition with a bit more of a practical emphasis and possibly more specialization.

Hopefully, the rationale behind our competition and the case that we presented to the AIAA and NASA will eventually lead to the creation of a competition that will be sustainable for long enough to be a huge benefit to both the robotics and aerospace communities.

Overview

When the competition was being designed, a lot of our ideas were based on the Lunar Regolith Excavation Challenge that is sponsored by NASA and hosted by the California Space Authority. The idea of designing a robot that can autonomously excavate and transport lunar regolith is an idea that originated in NASA's Challenge. However, the main goal of their Lunar Regolith Excavation Challenge is to use the resources and ideas of industry to try to produce a viable technology that can be used in upcoming lunar missions. Robots developed by NASA will hopefully be landing on the Moon by 2015, and people will be arriving by 2020. Their competition is not designed to draw in student teams from universities; it is designed to attract small companies and startups that compete for a $500,000 prize and visibility to NASA. Future contracts and job opportunities are as beneficial as the prize money. NASA's Regolith Competition is where the inspiration for the proposed competition came from. We felt that the lunar challenges presented in NASA's competition were important and were worthy of being investigated not only by companies and corporations, but by colleges and universities as well. However, we did not want college students to have to compete against seasoned engineers with heavy financial backing.

The decision was made to take the regolith processing idea behind NASA's Lunar Regolith Excavation Challenge and build a new competition around it that would be specifically oriented towards the schedule and budget constraints of university backed college students. Rather than trying to produce a piece of viable technology and offering a large sum of prize money, the focus of our competition became trying to help students learn how to work in interdisciplinary teams and gain experience from each other, with a modest amount of prize money as added incentive. The competition would also help to create the next generation of space technologists, who in the future might participate in the next generation of NASA Challenges with their respective companies. But the main draw for competitors in this competition is putting innovative engineering students into the spotlight and having them be recognized by people from other universities and in industry. A competition such as this would provide an invaluable place for companies to come and look for possible interns or recruit employees. Students would be able to show off what they can do in the hopes of drawing the attention of a potential employer. This competition could also lead ambitious students to create their own startup companies with the help of other people from the competition.

Another distinction between our competition idea and the NASA Lunar Regolith Excavation Challenge is that the NASA Challenge is a one time competition, meaning that once a team wins it, there will not be another running of it. Because this competition is going to cater to college students, we want

to have a competition that takes place annually, so that each new student class can have an opportunity to compete if they are interested. However, in order to make the competition an annual event, different tasks and problems for different years will have to be thought up in order to keep competitors coming up with new solutions. This allows the competition to take on multiple aspects of the lunar regolith processing issue, apart from simply excavating and transporting it. By doing this we hope that our competition will be able to thrive and keep people interested and coming back for at least a decade.

It is difficult to compare the two competition ideas in a standard pros and cons manner, because they are in essence set up to accomplish two different tasks. The NASA Lunar Regolith Excavation Challenge is set up so that companies can compete against each other to produce the best design for an autonomous lunar excavating robot that will potentially be used by NASA in future lunar missions. Our competition is set up so that student teams compete against each other, but not necessarily to produce the best design. Obviously, the best design will be recognized and rewarded, but the main point of the competition is to get students into the habit of working together and observing other teams' designs to gain new ideas and inspiration. That way, if the university decides to sponsor the team again next year, they can take the experience they gained in the previous rounds of the competition to produce a more advanced design the next time around.

There is no rule that denies college student teams the opportunity to enter NASA's Centennial Challenges. Any team that wants to participate and pays the entry fee can compete. However, the NASA Lunar Regolith Excavation Challenge timeline is inherently unfriendly to college students, and makes it difficult for a team to be assembled and field an entry for the competition. The amount of money that is at stake in the NASA Lunar Regolith Excavation Challenge is certainly something to be considered also. A prize that is that large changes the event by encouraging secrecy and creating intellectual property issues. A competition focuses on education requires openness and transparency, with incoming teams building on the work of previous teams. That is why we feel a competition like ours is needed. It takes the same concepts and intriguing ideas behind the NASA Lunar Regolith Excavation Challenge but houses them in a competition that is more easily accessible to student teams. The payoff for winning our competition would be significantly less than that of the NASA Lunar Regolith Excavation Challenge, but over time the mix of cooperation and competition will lead participants to learn more and will advance the field more rapidly.

Overall, there are trade offs between the two competitions. The NASA Lunar Regolith Excavation Challenge offers a large amount of compensation for a first place winning entry, but has a field of competitors that have a lot more resources and experience as well as a better suited schedule than

the average team of college students. Our competition idea would have a smaller payoff for first place, but would be easier for a college level team to enter on an annual basis. Also, participants who produce a reasonable product should be able to get academic credit for their efforts. We feel that our competition would be better suited and would appeal more to the general college student audience, but in the end, it will be up to the college students themselves to determine which competition idea is more appealing.

Methodology

Primary Objective: AIAA Conference

The first big step towards testing the reaction to this proposal came when the American Institute of Aeronautics and Astronautics (AIAA) held a Regional Chapter leaders meeting and a student conference at the Applied Physics Lab of John Hopkins University in Laurel, Maryland on November 21st and 22nd 2008. This Conference was called the Young Professional, Student and Education (YPSE) Conference and it provided an opportunity for students and educators to present their aeronautics and astronautics research to their peers and interact with fellow members of the AIAA community. The Board meeting was a review of activities and plans by the ten active chapters of AIAA Region I covering the northeastern United States from northern Virginia to Maine. After hearing about this Conference, we immediately recognized it as a way for us to champion our project proposal to prominent members of the AIAA and see if we could get them interested in it.

We attended this Conference and presented our project proposal to a group of interested attendees (including Andrew Petro, the Program Executive of the Innovation Incubator and Centennial Challenges Office at NASA) as well as some of the AIAA Regional Advisory Council members. The idea of a college-level lunar-themed robotics competition received a lot of praise and spurred a lot of interest amongst the AIAA members that heard the main presentation. We were also allocated ten minutes of the Regional Advisory Council (RAC) meeting and distributed a brief proposal. Some of the council members were very encouraging and a few went out in the hall with us after our time was up and talked with us for half an hour about other groups doing competitions that were analogous in a way and other design contests that the AIAA had sponsored for students in the past. The ambitious nature of our idea seemed to appeal to them. By the time the Conference was over, we had successfully informed Mr. Petro and several of the highest ranking members of AIAA Region I of the competition idea, and exchanged contact information with them.

There were several ways that attending this Conference was beneficial to our project. First, we were able to inform the members and leaders of the AIAA about the rationale behind the project proposal and gauge their response to the ideas of space technology as a highly interdisciplinary field and the AIAA becoming a sponsor of an interdisciplinary competition should the idea become a reality. The AIAA would be the perfect sponsor for a college-level lunar-based robotics competition because they have a

history of sponsoring engineering-based design challenges and are concerned with recruiting more people to the aerospace field. They would also likely be interested in a competition involving an extraterrestrial setting, even though the majority of the members are involved in aviation rather than spacecraft. Second, the Conference allowed us to inform a specific, well placed member of the NASA administration about the project proposal and allowed us to discuss how our idea fit in with their current lunar-themed competitions. Andrew Petro, a competition executive from NASA, attended the Conference upon our recommendation and served as our source of information on NASA and their policies.

The discussion with Andrew Petro after our main presentation went very well, although he seemed more interested in pushing the CSA to make his NASA Lunar Regolith Excavation Challenge more friendly to college students as opposed to shifting resources to a purely student competition. Our discussions with Mr. Petro began when he arrived at the Conference for our presentation and we noted that he observed the reactions of the audience of AIAA members and other student and conference attendees with interest. Our presentation provoked a lively discussion with the audience members, mostly supportive, involving people wanting to add to our list of fields from which aerospace would need to recruit while developing a lunar infrastructure. We were chided for not going far enough – though the presentation was later awarded an honorable mention at the Conference. Having received optimistic feedback from the people who attended our presentation, most notably Mr. Petro, who described other students as less practiced, less prepared, and less coherent than we were, we settled into a private discussion with him in the hall. We brought up several different issues and aspects of our proposal that we thought he would find most interesting. He then took the discussion in an unexpected direction.

Mr. Petro began to change the subject subtly. He starting talking about his disappointment in the fact that so few colleges had entered the NASA Lunar Regolith Excavation Challenge, whether individual companies or universities had an advantage, and soon he was brainstorming with Professor Wilkes and us about how to make the upcoming NASA Lunar Regolith Excavation Challenge more student friendly. Before we knew it, the discussion had moved to what WPI might do differently if it teamed up with AIAA Region I to run the next NASA Lunar Regolith Excavation Challenge and what the schedule would be if the goal was to increase college team involvement. When Professor Wilkes said that the idea of running the next NASA Lunar Regolith Excavation Challenge would only be of interest as a way to launch our student competition to follow, the key moment had come. We brought up the question of whether NASA would provide ten percent of the NASA Lunar Regolith Excavation Challenge prize money to such a contest, but provide it for ten years running. In effect, we were asking whether or not Mr. Petro would consider the idea of having one fewer Centennial Challenge in exchange for supporting a ten year student event. Mr. Petro basically brushed off the question, saying that the kind of prize money we

were talking about "should be no problem" and could be raised from several possible sources. He then explicitly noted that he had the authority to restructure future NASA contests but was currently thinking of having Lunar Regolith Challenges about once every five years. We closed our discussion by talking about the value of having a contest every year and making it open to everyone, especially college alumni who had already competed in a student contest as undergraduates. Those interested in making a career commitment could then participate in it again whether they were employed or in graduate school. Mr. Petro seemed intrigued by this idea, but made it clear that his current focus was finishing out the current NASA Lunar Regolith Excavation Challenge and producing a winner in the next iteration of it.

The question about whether NASA was disappointed enough in the performance of the California Space Authority (CSA) running the competition to be openly seeking a new contractor was unavoidable. However, NASA did not pay the CSA to run the contest; they had to do their own fundraising. NASA only provided the prize money and the simulated lunar regolith for the competition. Even reserving the prize money was complicated for NASA since all allocated money has to part of an annual budget allotment. The prize money that NASA provided was in a special account, tucked away until Mr. Petro declared a legitimate winner of the NASA Lunar Regolith Excavation Challenge. Mr. Petro did not need this money reauthorized each year and, as they were initiated by one of his predecessors, this would really be the first year that he would be in a position to oversee the contractors running the remaining NASA Centennial Challenges.

The result of this meeting was a flurry of activity preparing a draft proposal for Mr. Petro about WPI's willingness and ability to take over running the NASA Lunar Regolith Excavation Challenge. We thought the main issue would be raising $50,000 from contestants to cover costs. There would have to be at least twenty entry fees at $3000 each minus "scholarships" to a few promising teams that could not raise the money themselves. What was really desired at that point was a reaction to the proposal from the fifty colleges and universities most able and willing to field teams if they knew about the opportunity. If twenty percent of them were interested in the idea then there would be little risk. Ten college teams and fifteen to twenty returning competitors from the last round of the NASA Lunar Regolith Excavation Challenge would easily be able to cover the anticipated costs of running the Lunar Regolith Excavation Challenge for another year. However exciting as this possibility was, the WPI robotics program members really did not think that the CSA would give up running the contest again, although they might want WPI as a partner in running the contest. We stayed focused on the question of what should happen next, after the NASA Lunar Regolith Excavation Challenge was completed. We were also aware, however, that if WPI took over the NASA Lunar Regolith Excavation Challenge there would be momentum in favor of our proposal.

At the end of our lengthy discussion with Mr. Petro, we had several new ideas and problems to consider. Perhaps most notable among them was the possibility of NASA fronting the prize money for our competition. This was important for two reasons. One reason is that it would give NASA a direct stake in the competition and would allow us to recruit experts from NASA to set up the rules and serve as judges. Another reason is that the idea of sponsorship would be more appealing to the AIAA if they knew that another organization would take care of providing the prize money, leaving them to cover only the costs of running the event. Mr. Petro also brought up the idea of opening the competition up to small businesses as well as universities. We said we thought it would not be a good idea because college student teams would feel they had a disadvantage against corporate teams. Mr. Petro countered by saying that the businesses would feel they were the ones at a disadvantage against university teams. The discussion was ended with one of us saying that either way, neither group would feel it was fair so they probably shouldn't compete against each other because we wanted a level playing field. This idea of small businesses and universities allowed to enter the same competition was ultimately left unanswered at the time, but it gave us a new angle to consider for our proposal.

After our discussion with Mr. Petro, we gave a brief presentation to the AIAA Regional Advisory Council members, including the AIAA Region I Director Jon Malay, who specifically found our idea to be interesting. We presented our proposal orally to the council members, handed out written copies of it, and asked them about the possibility of AIAA Region I sponsorship for our competition. The RAC members gave us positive feedback, and while they didn't commit to a definite sponsorship, they certainly didn't reject our idea either. They felt that because our proposal dealt with a competition potentially involving universities from all over the country, Region I of the AIAA was not the appropriate authority to ask for a sponsorship. They told us that the AIAA National Office would be a more suitable place to look and, because they were intrigued by our proposal, Director John Malay offered to represent our idea at the next National meeting. They were also intrigued by the idea of not having to raise the prize money from corporate sponsors, and it was clear that possible partnership with NASA was appealing. They left us with several leads to follow, including a list of aerospace-themed design contests that the AIAA was currently involved with. Overall, we received positive feedback and definite interest from both the AIAA (which was in an excellent networking position to publicize the contest and give it legitimacy) and NASA, and having a proposal backed by both of those organizations would certainly be a hard idea for WPI to reject.

The YPSE Conference was a great opportunity for us to let people know about our project. It went a long way towards helping us achieve our primary objective of championing our idea to the people who could make it a reality. It provided us with new contacts, new ideas, substantial feedback, and a lot

of other information that was useful later in the development of our proposal. The most important information that we took away from the Conference was the contact information of Andrew Petro and John Malay, the interest of NASA and the implication of a decision by Mr. Petro's office to front prize money. This would tilt the other sponsors in favor of the idea and would not cost NASA anything if it was received as a restructuring of the future Centennial Challenges budget. There were influential AIAA leaders that liked the idea of having the AIAA be a sponsor and the possibility of them discussing our idea at a national level as part of a plan to diversify the field and increase membership. This information gave us a lot of new things to consider, and a whole new list of potential questions that we needed answers for. Overall, the YPSE Conference was a great success as a stimulus – response feature in our research design. We gathered valuable information and leads we needed to pursue our idea further.

Primary Objective: Survey Instrument

In order to sufficiently back up our contention that this competition would be popular with both students and faculty, we knew that we would need input from potential participants. We determined that the best way to do this would be through a survey. There is no better way of finding out what would be the best way to form a team of college students than asking college students themselves to evaluate a few scenarios. A close second is getting opinions from the faculty and staff that will likely serve as their mentors and coaches, publicize the event, and recruit students with the right interests.

After analyzing some relevant literature on surveying, we set out to determine what the sample should be. A cluster method was chosen, using nearby colleges and universities that we deemed had the potential to field teams for our competition as the cluster. This potential was determined by the presence of one or more of the following at an institution: an AIAA student chapter, team coaching involvement in FIRST, some sort of Robotics Engineering undergraduate or graduate degree offered. The sample space was defined to be New England (Region 1 NE for the AIAA). The sample we used was pulled from a list of colleges that had previously participated in the FIRST competitions.

Once the sample had been determined, the following rough draft of objectives was developed, from which the actual survey questions were formed:

- Gauge interest among faculty and students on specific aspects of the competition
- How much of a monetary commitment would be reasonable?

- What skill base is present at most of the chosen institutions?
- Are there other competitions that they know of with similar objectives that would compete with ours?
- If students could get credit for participation, would it make the competition more appealing? Would the program faculty be willing and able to give credit?
- Explain how the competition would build year to year and ask if there would be any negative issues with that
- Can multidisciplinary or interdisciplinary teams feasibly be put together?
- Will this competition be
    - Likely supported by administration, faculty, and students
    - A significant educational opportunity
- Are there obvious existing mechanisms (club, project, class, etc.) for forming teams?
- If your institution has not allocated the resources to sponsor a team for this competition the first year, knowing that it is expected to run for five to ten years, would/could your institution generate the necessary resources and sponsor a team in future years?
- What schedule would best accommodate the academic school year and the interests of students and faculty?

Our project was nearing the end of its designated time allotment and it had become clear that the time left would be insufficient for the survey and the final report to both be completed properly. It was decided that the survey would be completed but not issued to allow enough time for the project report to be written on schedule. The survey, included in the Appendix, will be sent out at a future date, probably by a future IQP team.

Secondary Objective: Possibly hosting the competition at WPI

It would be beneficial if WPI was willing to host our proposed competition, but it was not crucial for the success of our IQP to have WPI adopt the proposal since other hosts could be found. Thus it was determined that a secondary objective would be to see if WPI would be willing to host the competition, if not now, then at some point in the future.

Ultimately the administration at WPI would have the final say in whether or not WPI should host this competition. However, if we could elicit enough support for our idea among the relevant members of

the faculty, staff, and/or students, our proposal would be that much stronger. Since, as described in the Background Information Section, the original two problems we set out to solve were based in the fields of Aerospace and Robotics Engineering, we decided to arrange to have our advisors approach those faculty members while we tried to get the reactions from students in those majors.

Several different groups of people on campus were approached so as to gauge their enthusiasm and support for our idea. The first group that was approached was the professors in the Aerospace Department. They were not interested at all, seemingly convinced that WPI Aerospace would not be focused on the Moon in the near future, as no current faculty member was focused on lunar infrastructure development. However, when our idea was presented to the WPI student chapter of the AIAA, they were very excited to hear about a college-level competition with a lunar theme. They were surprised they hadn't heard of NASA's Centennial Challenges, which we mentioned in describing the Lunar Regolith Excavation Challenge as our inspiration. At the end of our meeting, they decided that they would have to look into current competitions more before they decided whether or not to take part in any. Some time later, after seeking out Professor John Blandino of WPI's Mechanical Engineering Department as an advisor, a group of six Aerospace students decided to enter in another of NASA's competitions co-sponsored by the National Institute of Aerospace (NIA). This competition, Revolutionary Aerospace System Concepts Academic Linkage (RASC-AL), happens to have a lunar theme and is for university students, similar to the competition we are proposing but without the robotic focus. This shows the impact we had on Aerospace students, who in turn transferred our interest in the Moon to at least one Aerospace professor at WPI. The concept these WPI students are entering in RASC-AL with is a ballistic "hopper" vehicle they call an Advanced Ballistic Lunar Explorer (ABLE). More information on their design as well as the RASC-AL contest can be found in the Appendix.

We also sought feedback from WPI's Robotics Engineering students and faculty. The students were invited to attend a practice run of our presentation prior to the AIAA YPSE Conference, but they all declined. Part of the robotics program faculty was excited about a college-level robotics competition that could be a follow on to FIRST, but they felt that it would lose a great part of its value to WPI if it was not held on our campus.

This response from WPI was less positive than was hoped for. It seems that overall WPI is less than enthusiastic about hosting our competition. Since having WPI as a host was not crucial for the success of our competition proposal, we merely made a note of it and decided to look elsewhere for potential sites; wherever the simulated regolith for the NASA Lunar Regolith Excavation Challenge ended up being located seemed like a logical place. Mr. Andrew Petro, a Program Executive from NASA,

seemed disappointed that the simulated lunar regolith used for their Lunar Regolith Excavation Challenge was only being used once a year for that competition. This led us to believe that NASA would welcome the idea of having a permanent or semi-permanent lunar test bed set up somewhere to be used by their competition and ours, as well as other activities throughout each year.

Secondary Objective: Our ideas about the changing field of aerospace

In order to promote our competition, we determined that it would be necessary to first convince the AIAA that the field of aerospace was indeed changing into an interdisciplinary field. This was one of our main objectives during our presentation at the YPSE Conference, the others being championing our competition as a way of preparing students for this changing field and encouraging the AIAA to consider sponsoring it. This was considered to be only a secondary objective for our project as it was seen as only a means of championing our idea. In the first half of our presentation we discussed the following points (the entire presentation can be found in the Appendix).

It is expensive to send rockets, satellites, shuttles, and other objects into space. Once out of the Earth's atmosphere, there is currently no place for those rockets to refuel before heading to their destination. Thus before they lift off, a rocket or shuttle would need to have all the necessary fuel to pull out of Earth's gravity well, travel all the way to their destination, and possibly even travel back to Earth. This makes the rocket much heavier than if it only needed sufficient fuel to get into outer space. It would be much more cost effective if there were space bases where these rockets could refuel before continuing to their destinations.

We believe that Earth's moon is the most logical place for the first space base. We already know a fair amount about it. It is the closest celestial body to Earth, making it a convenient refueling station for shuttles once they escape Earth's gravity well, which is six times greater than that of the Moon. It could also be the "base" that provides the liquid oxygen for several in-space orbiting fuel depots that could be located around the Earth and Moon, as well as other celestial bodies. Then one does not even have to land on the Moon to refuel. Also, there are valuable resources on the Moon in the lunar regolith that would make a lunar base economically appealing. These resources include metals (some precious), helium 3 (used as fusion reaction fuel, dropped by solar wind and thus not found on Earth), and liquid oxygen (used in rocket fuel). The regolith itself could also be used to provide radiation shielding for the base**.**

Considering sustainable space bases as a means of gathering extraterrestrial resources and refueling rockets in space is causing scientists and engineers to think differently about space. In order to establish these space bases as well as keep them running, we would first need to figure out how to build them. Due to the hostile environment, one would want to do things autonomously whenever possible, and remotely whenever not, keeping humans away from the hostile parts of the environment and the explosive fuels as much as possible. This means that robotics will be used extensively. Once the space bases are built, we would still want to use as few humans as possible, but we would likely end up with a few humans living and working in space, so this will also have to be taken into consideration. Still, this is probably ten percent of the human workforce, with the other ninety percent manipulating and monitoring semi-autonomous devices from the safety of the Earth.

Assembling, maintaining, and operating these space bases will require more disciplines than those that have traditionally been involved with space. Aerospace, Mechanical, and Electrical Engineers would still be in just as high demand, however, they would be joined by several other groups of specialists. The bases will have to be designed and constructed, which would involve Civil Engineers and Architects. The lunar regolith will need to be moved around and manipulated, which would best be solved by the use of robots. It would also need to be processed and sorted, which would require Mechanical and Chemical Engineers. If there are to be humans stationed on these bases, then there would need to be food and water, thus providing a need for Agricultural Engineers, and the unique extremely isolated social environment would require Psychologists to mitigate the mental stress of living in confined space with few other people for long periods of time.

All of these different majors would need to come together in order to create a single, sustainable space base. This would be a substantial managerial challenge dealing with running a man-machine system in an alien environment. This could be accomplished in two similar ways: one involving multidisciplinary teams where each member has a different expertise and only did tasks relating to that expertise, and the other involving interdisciplinary teams where each member has expertise and experience in more than one field. Interdisciplinary would be the better of the two as it allows for knowledge of the unique problems and situations that arise from the overlap of certain disciplines. It would be best to develop these interdisciplinary team working skills at or before the college level. That way, young professionals can be brought into the industry already prepared to face some of the expected problems of planetary colonization. That is where our competition comes in. At this point our presentation went on to describe the specifics of our competition idea. The idea that the field of Aerospace Engineering is going interdisciplinary was very well received, almost unquestioningly so, by the AIAA members and other audience members who were present for our YPSE Conference presentation.

The AIAA members seemed to like the idea of aerospace as a large tent which will have to accommodate many different kinds of expertise rather than being a specific specialty. Of course, from an AIAA perspective, this also broadens the potential membership pool. One can recruit people interested in the space environment and industry without having them be trained as aerospace engineers. For the future, one needs to think about what common core of knowledge they all should have about the space environment to go with their other disciplinary expertise and degree. AIAA has an opportunity in this development, and if it fails to accommodate this change in the field, a new organization will emerge to serve the hybrid professionals that will be produced by the needs of industry in the next fifty years.

Proposal

We are proposing that the AIAA, with the cooperation of NASA and WPI, create a college-level robotics competition focused on lunar development issues. There will be a lunar theme at first with the possibility of other themes in the future. Each *theme* is planned to run for five to ten years with a different *goal* each year. In a given theme, each goal will build upon the system produced the year before in a progressive fashion. All of these themes will focus on practical solutions to real problems. The competition itself will be run in a manner that will be tailored to fit college students' unique needs and schedule. There will be a monetary prize of at least $10,000 and no more than $50,000 for first place and the top three design solutions will be posted with source code, electrical and mechanical schematics, and other relevant design materials so as to be available to all competitions in the future. Each team will have to pay an entrance fee of $500 to $3,000 to enter the competition, depending on the size of the prize. Teams are encouraged to be interdisciplinary or at least multidisciplinary. We decided to name this competition the Lunar Development Robotics Competition (LDRC) in honor of its first theme, which we hope will be run from 2010 to 2020.

The first theme of this competition will be robotic solutions to lunar development issues involving the handling of regolith. This will assist both the Aerospace Engineering and Robotics Engineering fields. Robotics Engineering is a rapidly developing field. There is a lot of effort being made to accommodate this sudden push for automation, including new Robotics Engineering majors in universities and robot themed competitions. Our competition can build upon a very popular robotics competition series, FIRST. However, this must be done carefully so as to enhance and extend the network rather than draw off the college talent needed to support the high school initiative. Above all they can't compete for resources and volunteers. Another pool needs to be tapped to support the new initiative. We propose to turn to the aerospace community and NASA in particular. A range of companies and universities with interests in robotics are involved in the FIRST Community, either through sponsorship or coaching. A great many students participate in its various competitions, the largest of which being the FIRST Robotics Competition for high school students. However, FIRST also sponsors another robotics competition for high school students and one for younger students aged 9-14, but not currently one for older students. Many members in the FIRST Community, and thus a lot of key players in the robotics field, are eager to see a follow-on robotics competition for college students. If implemented, our competition series would fulfill that desire and keep the fire of excitement for robotics going. Interest in

space, unfortunately, is not currently as broad and contagious as that of robotics. However our competition can borrow from the latter's excitement to further bolster interest in the former.

Space technology and exploration is going interdisciplinary and branching out from traditional aerospace studies. Thus majors that are not traditionally space-oriented will need to learn about the special considerations that need to be made when dealing with space environments. Our competition will allow students with an interest in space to explore these environments while in college, just before heading out into their chosen field. We believe that our competition will fill both of the niches in the Robotics and Aerospace Engineering fields, and provide some interesting application synthesis, professional hybrids, and even some new corporate ventures.

The competition will start with a simple but challenging goal to familiarize the students with the lunar environment, and then progress to more complex goals building upon the ones that came before. The exact goals will be determined at a future date, but to give a general idea of the competition's annual progression:

> The first goal will be little more than robotic maneuverability in a simulated lunar regolith arena with obstacles like those that would be found on the Moon. Following that, the second year's goal would be manipulation of regolith in some form, such as plowing, digging, or otherwise moving a certain amount of regolith in a certain amount of time. After digging a random hole of a certain size within a time limit, the next goal would involve moving regolith more specifically, such as clearing out a specified area of the arena and bringing that regolith to another specified area. For example, the robots might be required to pour the regolith into a receptacle for later processing or fling regolith onto a building-like structure in a pit without damaging the structure so as to shield it from radiation. The year after that, the goal would be to extract a useful resource from the raw regolith obtained from a given site or show how it could be used locally on the Moon, such as turning it into glass to later be a component in a solar collector. The fifth year, the goal would be tunneling and creating an underground chamber suitable to be a radiation protected greenhouse. If this is to be the final goal in the lunar robotics theme, it would smoothly transition into an extraterrestrial civil engineering theme or one based around providing for life in hostile space environments. Contrariwise, if at the end of the fifth year there is a perceived need for the use of robotics in non-lunar environments, such as Mars, and it is determined that the robotic systems designed for the Moon are not suitable, a Martian robotic theme may be the next one.

Each year, the entries would be expected to be able to perform at least satisfactorily in the terms of the previous year's goal in order to do well with the current year's (for example, a robot cannot easily

move regolith into a receptacle if it can neither manipulate regolith nor move itself effectively). Once the lunar robotic theme has run its course, another five to ten year theme will take its place. This follow-on theme will likely pursue either space issues or robotic solutions. Which course it takes is dependent on future interest and perceived needs at that time.

In order to keep teams that did not win a certain year from having an unfair disadvantage in the following years and to foster an open educational atmosphere, the teams with the top three designs from the previous competition will be required to disclose everything to incoming teams, open source, open schematics, etc. By doing this, their designs will be available for all future participants to use and improve upon.

A lot of educational competitions have a sport-like or game-like atmosphere. This is appropriate for lower grades as it encourages younger students to pursue particular careers by emphasizing how much fun they can be. By the time a student reaches college, however, they are thinking ahead to when they enter the work force and so are trying to develop the skills they will need in the field. It would benefit them greatly if they could have some real world problem solving experience prior to graduation. That is why we chose to have our competition oriented around solving problems that exist outside of the competition. Additionally, in a game-like competition, winning is more likely to require correctly applying existing knowledge to the problem presented; whereas in a competition with practical problems, new knowledge will likely be developed while teams attempt to succeed in the competition.

Other details of our competition idea were similarly designed to cater to the needs of college students in their junior and senior years when majors are settled but minors are still under consideration. We see a “space studies” minor with credit for participation in the competition as a valuable way to signal one’s interest in a hybrid degree and career involving the space industry. The schedule for the competition, including when the competition takes place and the amount of time before that the goal is officially announced, will be set up to fit neatly into the normal academic year. By that we mean that one knows by April, when one is signing up for courses the following year, that the competition is on, what the challenge will be, and the designs from the previous challenge. This means that the competition should be held in January or February, with the outcomes of the competition made available by March. Rather than competing with various companies, college teams would be allowed to have them as mentors, coaches, and/or sponsors. This would provide a lot of networking opportunities between different companies and colleges, including introducing students to potential future employers.

That is our competition concept as it currently stands. This has sparked various discussions and it is our hope that it will continue to do so until it is made a reality. Some of this discussion involved

merging the NASA Lunar Regolith Excavation Challenge and our idea, and while the two competitions did indeed influence each other a great deal, our decision is to keep them separate and complementary.

Results / Analysis

After giving the presentation at the Young Professional, Student and Education Conference, we had obtained enough positive feedback from the officials of AIAA Region I to show that they were interested and some were even excited about our idea. However, we also learned that they thought that a competition idea such as ours should be considered by the officers at the AIAA National level because of the desirability of having entries from universities from around the country. Based on this, we drafted a new version of our RAC Meeting Proposal and gave it to AIAA Region I Director John Malay to take to an AIAA National Meeting in Orlando Florida in January 2009.

After the conference, Mr. Malay got back to us in early C Term saying that AIAA National saw potential in our idea, but needed more definite information about our and NASA's intentions before they would commit to some kind of financial or other sponsorship. They specifically wanted to make sure that NASA was firmly focused on returning to the Moon in future space missions. There is a debate going on in the space community as to whether the United States should return to the Moon, or whether the focus should be on making attempts to more extensively explore Mars and visit asteroids. AIAA National wanted to make sure that NASA stays focused on the current policy of returning to the Moon and planning to develop lunar bases there starting in 2020 before they sponsor a competition based on possible lunar problems. This response did not represent the same enthusiasm and excitement that we saw from the majority of the people at AIAA Region I, but it was not all bad news either. It seemed as though AIAA National thought that our idea was interesting, but would possibly be too much of a risk for them to take on without knowing more information about what they would have to do as a sponsor.

Another beneficial response that we obtained during the AIAA Region I Conference was the response we got from Andrew Petro. Andrew Petro liked us personally, complimented us, thought we presented well and were a good representation of the college student audience that he wants to attract to the NASA Lunar Regolith Excavation Challenge. However, instead of pulling resources away from the current NASA Centennial Challenges and moving them into a new student-oriented competition, he instead told us that he wanted to make the current NASA Lunar Regolith Excavation Challenge friendlier to college students. He wanted to make changes such as shifting the schedule around so that college students can participate in the Lunar Regolith Excavation Challenge more easily without having to worry about the competition interfering with school work, possibly giving academic credit to students who

participate in the Lunar Regolith Excavation Challenge, etc. When we discussed our project, however, we learned that NASA might consider funding us because our low amount of proposed prize money was considerably less than other contests that NASA funds, such as the Centennial Challenges and RASC-AL. We also discussed the possibility of having our competition act as an introduction to the larger NASA Lunar Regolith Excavation Challenge. By doing this, our competition with its high percentage of college students would draw more college students into NASA's Lunar Regolith Excavation Challenge as well, which is what Mr. Petro wants. This would get our competition idea off of the ground, and Mr. Petro would get the larger college student audience that he wants for the NASA Lunar Regolith Excavation Challenge, benefiting both of us from this arrangement.

The overall results of the AIAA Region I Conference, the RAC Meeting we attended there, John Malay's trip to the AIAA National meeting, and the meetings with Andrew Petro were positive. We learned that sponsorship and/or financial support for our competition from both the AIAA and NASA was within the realm of possibility. However, it was certainly not definite either. The circumstances were still too uncertain; both organizations wanted someone to test the competition idea by trying it so that they wouldn't have to incur the risk at the outset in assessing its promise.

At this point, WPI starts to come into play. We recognized WPI as a potential place where the student competition could be run. The original idea that we came up with was that WPI would host the next round of the NASA Lunar Regolith Excavation Challenge in order to bring the AIAA and NASA in and help to convince them that our idea would be doable. NASA and the AIAA would become involved on the WPI campus, and our idea would have a place to settle in once NASA's Lunar Regolith Excavation Challenge was over. If WPI hosted the Regolith Excavation Challenge, we would already have the regolith pit and other necessary hardware to start running our competition, although there would be some cost in housing it properly. This would be a huge step forward in the process of making our competition a reality.

As noted above, we soon found out that there were problems with our initial idea. The Aerospace Department at WPI was not particularly interested in lunar activity or space in general. They didn't want anything to do with the NASA Lunar Regolith Excavation Challenge, nor did they particularly want to see it come to WPI. Moving the regolith to WPI would be expensive and difficult, not to mention that WPI might have to pay for housing the simulated regolith, which is potentially expensive. The whole process was considered to be an overall hassle. WPI would also have to find a physical place to put the regolith pit and other hardware for the Lunar Regolith Excavation Challenge for when we host it.

There was also support for the idea, however. When we talked with Mr. Petro at the AIAA Region I Conference, he told us that he was unhappy with the organization currently hosting the NASA Lunar Regolith Excavation Challenge, the California Space Authority (CSA). He hinted that he might want a new group to take over hosting the Lunar Regolith Excavation Challenge. Unfortunately, NASA only provided the CSA with the prize money and the regolith needed for the competition. The CSA did their own fundraising to pay for running the competition itself. Hence, Mr. Petro did not have enough sway to displace the CSA and demand a new host. Despite this, Mr. Petro implied that WPI would do a better job of hosting the NASA Lunar Regolith Excavation Challenge and would be a better place to do it.

After the idea had been thought over, a set of conditions under which WPI would take on the NASA Lunar Regolith Excavation Challenge were formed. The Lunar Regolith Excavation Challenge would have to be made more college student friendly, in terms of its schedule and the ease with which a team of college students could field an entry. There would have to be at least thirty entrants to the Lunar Regolith Excavation Challenge, each of whom would pay an entry fee of $3000, so that WPI could stand a chance of running the competition from a financial standpoint. Finally, NASA would have to still provide the simulated regolith for the Lunar Regolith Excavation Challenge, as well as the prize money. If NASA also paid half of the cost of running the competition, WPI would challenge the CSA for the opportunity to host the next iteration of the NASA Lunar Regolith Excavation Challenge.

There were other possibilities for this NASA Lunar Regolith Excavation Challenge that were considered as well. One of these possibilities was that of WPI and the CSA teaming up to run the competition. The competition itself would still be in California because the regolith is already being stored out there, but WPI would play an active part in the competition as well. The California site would act as the “Moon” with the regolith pit and the robots maneuvering through it, and WPI would act as the “Earth” with students from the teams tele-operating the robots remotely from all the way across the country. This would create conditions similar to actual Earth to Moon communications and lag time. This idea, however, was not received well by people at WPI who were interested in NASA’s Lunar Regolith Excavation Challenge coming to WPI. Ken Stafford, a WPI professor who is particularly heavily involved in robotics, maintained that WPI would gain little benefit from being a part of the NASA Lunar Regolith Excavation Challenge unless the regolith pit and the robots themselves were located on campus. The idea was ultimately rejected, and discussions began again regarding WPI versus the CSA as the next hosting organization.

In addition to WPI and the CSA, we learned that the Colorado School of Mines was also interested in hosting the next round of the NASA Lunar Regolith Excavation Challenge. They wanted to

host the competition in Colorado, and they also wanted to make it friendlier to college students. They would have to pay to have the regolith moved out there from California Polytechnic State University, but it would be easier to move regolith from California to Colorado than it would be to move regolith from California to Massachusetts.

The final results of these debates, despite the interest shown by WPI and the Colorado School of Mines in hosting the next round of the NASA Lunar Regolith Excavation Challenge, was that the competition would remain with the CSA. The CSA already has the simulated regolith out in California and it was decided that things would just generally be easier if the Lunar Regolith Excavation Challenge stays there. However, soon after we learned that the NASA Lunar Regolith Excavation Challenge would stay out in California, we also learned that changes were going to be made from previous years. We learned that the CSA was attempting to team up with NASA Ames in Northern California to run the competition.

The competition would probably be hosted by and the regolith would be stored at NASA Ames instead of at California Polytechnic State University. The rules of the Lunar Regolith Excavation Challenge were also changed to make it easier in an effort to produce a winner this upcoming year. The rule changes involved allowing the robot to be tele-operated instead of requiring it to be completely autonomous, which would greatly reduce if not eliminate unintended or undesirable robot actions. If the robot gets stuck somewhere on the course, which happened often in past years, the operator can manually move it and have it continue with its mission. By doing this, the competition becomes much easier and more winnable, as well as more representative of how lunar robotics will be handled in the real lunar missions. The starting ramp will also be removed from the course because of previous problems with robots getting stuck on it. Robots participating in the Lunar Regolith Excavation Challenge still have to move as much regolith as possible into the receptacles within a certain time frame, and whoever moves the most regolith is the winner. The Lunar Regolith Excavation Challenge will be held in mid-August, which is still not a student friendly timeline, but it is still feasible for student teams to field a robot and enter the competition if they were already part of the competition in the last round.

The overall results of our IQP research were for the most part optimistic. We were able to determine that the AIAA saw potential in our idea and was excited about it, enough to maybe sponsor it someday when we have more definite information to go to them with. Unfortunately, our idea of a student only competition basically died in NASA, because although it would be possible for them to give us the small amount of prize money that our competition would require, they were unwilling to abandon the current NASA Lunar Regolith Excavation Challenge without having an actual winner. Once somebody is

able to win that Centennial Challenge, then Mr. Petro's office might be able to move on to something else. Also, from NASA's perspective, it is easier to modify an old competition as opposed to creating a whole new one. As of now, NASA's primary focus is on the current NASA Centennial Challenges and making it easier to produce a winner. This doesn't necessarily mean that they didn't like our idea, it just means that they just can't give us any assistance with it right now. It is possible that in the future, we will be able to get support and/or money from them once somebody has won the NASA Lunar Regolith Excavation Challenge.

However, after talking with the AIAA leadership and Mr. Petro and getting our idea under discussion by people in the aerospace industry, it is clear that we did spark some interesting thoughts and had a modest impact. It led to the debate over whether or not WPI could take on the NASA Lunar Regolith Excavation Challenge, and probably indirectly led to some of the changes that appeared in the rules of this year's NASA Lunar Regolith Excavation Challenge. The discussions about moving the Lunar Regolith Excavation Challenge to a new location let the CSA know that they had to make some changes if they wanted to keep the competition. Otherwise, another potential host might come along with a better way to run the competition (WPI or the Colorado School of Mines) and take it away from them. At the very least, our competition ideas helped to get the thought out there that the NASA Lunar Regolith Excavation Challenge had to be made more college friendly, and in the end some rules did change, but not the schedule, which we considered the most important barrier to student team participation.

Conclusion

At the start of our project, we identified two problems that we saw that we thought we could help address with our idea of a college student lunar-themed robotics competition. The first problem was that the robotics community is in want of a college-level robotics competition that could possibly act as a place for high school students who participated in the FIRST Competition to continue their involvement in robotics. There are some interesting regional and statewide competitions with college divisions, but no one has yet mobilized the broad FIRST network catering to secondary schools and added a college level program for that audience. In that arena the main competition seems to be the underwater robotics community which seems to have begun cooperating with the Office of Naval Research on both secondary school and college level contests with "missions" to accomplish under time limit.

The second problem was that the field of aerospace is heading for a change as the focus in space is shifting from exploration of space to building bases and later civilizations in space. The aerospace industry is going to need a new type of engineer who can deal with the new types of problems that this shift will produce. Our position is that by creating a college-level lunar-themed robotics competition, we can help to solve both of these problems. The proposed competition will give students with an interest in robotics a chance to continue their practical experience with robotics and it will also help to guide interested students into the new field of engineering that the aerospace industry is going to need in the future.

We formalized our ideas and presented them to members of the AIAA at the Region I Young Professional, Student and Education Conference and received mostly positive feedback. We also talked with Mr. Andrew Petro of NASA and members of the Regional Advisory Council, who gave us positive feedback as well as some new ideas to consider for the future of our project. These meetings and talks gave our idea a start and showed us that it had some merit.

Based on the feedback we received from the AIAA Conference, it was clear that we needed more definite information about how interested college students were in this theme for a contest and whether the possibilities that our competition would give them were of interest. We created a survey in an attempt to get some tangible data from universities with involvement in the fields of robotics and aerospace that we could use as evidence that the proposed event would be popular. The goal was for this survey to help bolster our case and possibly get AIAA and NASA more interested in the idea of sponsoring our competition.

In the end, after further discussions between WPI, the CSA, and Mr. Petro, we concluded that the NASA Centennial Challenges, including the Lunar Regolith Excavation Challenge, are going to be NASA's main focus for this year and only modest changes will be made to the format. It will not be reconceived and rescheduled so as to lead into a series of annual student contests. However, our competition certainly has generated definite interest amongst the people in the AIAA and at NASA that we presented it to, and we believe it also has enough potential to reshape future thinking about how to use the resources in Mr. Petro's office. Whether it is with the AIAA or NASA, or with smaller organizations like the National Space Society or the Moon Society, whether we get money from an outside sponsor or if we have to fundraise it ourselves, we believe that this competition will eventually happen at some point, and we hope that WPI will be heavily involved. Whether it is as the host or simply as a participating party, either way, WPI stands to benefit from the eventual creation of the proposed student competition.

Recommendations for Future Action

We believe that this project has great future potential, and because of that we feel that more research and continued involvement with this project would easily provide enough material for another IQP. In our project, we have taken some of the first steps that will be required to make our competition idea a reality. We made some initial contacts with important people at NASA and AIAA Region I, presented our idea to them, and received their feedback. We also observed some interesting discussions between the CSA, WPI, and the Colorado School of Mines regarding the future of the NASA Lunar Regolith Excavation Challenge. Based on these discussions and the feedback we received from the people at AIAA Region I and Mr. Andrew Petro from NASA, we feel that our idea for a college-level lunar-themed robotics competition may not be feasible at this point in time, but that it has definite potential for the near future.

There is still a lot of work that needs to be done. The survey instrument that we created and got through the IRB review process still needs to be fielded. We have also obtained a list from the FIRST organization with about a hundred contact people at different universities and identified at least twenty to thirty more to whom the survey should be sent. This survey would be an important step for future IQP groups because it would yield concrete data about how other groups of college students view the concept and theme. Based on the analysis of these data, future groups could determine whether or not the competition had enough backing from the college student audience to succeed as proposed and could further tweak our competition idea to meet student needs and opinions. These results could then in turn be used to help convince organizations such as the AIAA or NASA to sponsor the competition. Another important part of obtaining this data would be that future IQP groups will be able to maintain contacts with universities that responded favorably towards the competition idea, and hopefully be able to gain more insight from them as to why they liked the idea to begin with.

The next iteration of the NASA Lunar Regolith Excavation Challenge which is expected to be held at NASA Ames in California will also be important to future IQP groups. The new rules implemented in the contest are an interesting change, and the impact they have on the performance of robots in the competition should be noted and taken into account when designing aspects of our college student competition.

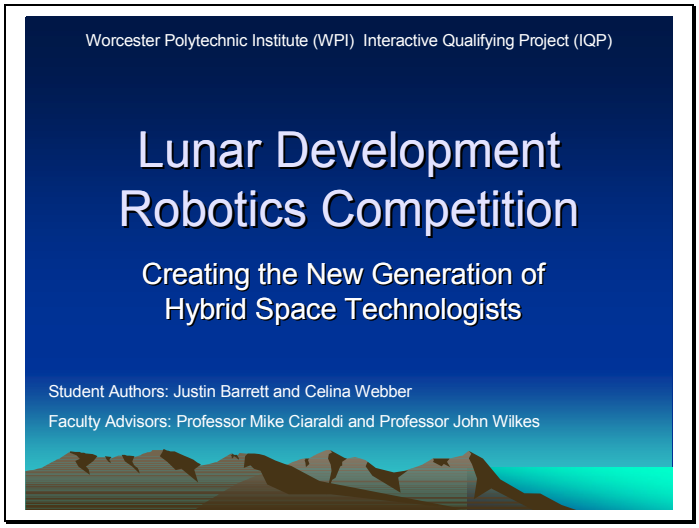
Some more definite consideration should be given to the costs of running and possible locations for the competition as well. There are many possible places, ranging from WPI or the Colorado School of Mines to NASA's Goddard Space Flight Center in Maryland. The feasibility of having the competition at each of these locations should be compared and analyzed.

Additionally, the contacts that we have made during this project with important people such as Mr. Petro and AIAA Region I Direction John Malay should be maintained, and they should be informed of any relevant progress with the project that they might be interested in knowing. Other new contacts might want to be established with people in the CSA or NASA Ames also, so that future groups can keep tabs on what is happening with the next iteration of the NASA Lunar Regolith Excavation Challenge.

Finally, future IQP groups should look more into the robotics side of our competition idea. The survey to be sent to schools involved in FIRST and the AIAA would be an important first step, but there is more information to be gathered. They should research other college-level robotics competitions and analyze their features to see what tends to contribute to their success and what tends to be their major downfall. There are documents written on how to run a good competition that they should read. Before this competition becomes a reality, the rules and logistical sides of the event need to be hammered out. It is likely that another IQP team will be able to work out these final details and be in a position to present a concrete Lunar Development Robotics Competition idea to those who would be interested in sponsoring it and making it happen.

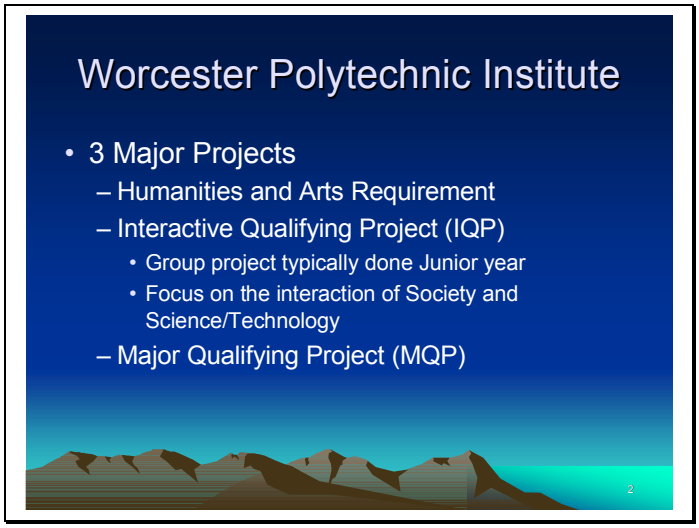
Appendices

Appendix A: AIAA YPSE Conference Presentation



Intro: Justin, Celina, WPI, Competition

We'll explain more of what we mean by Hybrid Space Technologists in a minute, as well as why we believe they will be necessary in the near future and how our Competition will encourage them. Then we will focus on our Competition and why you should be interested in it.



Humanities and Arts Requirement- typically done Sophomore year, series of classes ending in Seminar/Practicum.

MQP- Capstone Project, typically done Senior year.

IQP is also interdisciplinary. We're doing our IQP- mention last as transition.

Background Info

- Scientists and Engineers are Thinking Differently about Space
- Considering Sustainable Space Bases
  - Gathering other-worldly resources
  - Robotic processing
  - Living and working in space
  - Refueling rockets in space

3

Where to Start?

- The Moon
- Why?
  - Closest celestial body to Earth
  - Regolith contains valuable resources
  - Easier to get resources to Space
  - Already know a fair amount about the Moon

4

Space Technologists

- 30% of current Space Technologists will reach retirement age in the next few years
- Need to be replaced
- Also needs to be new kinds of Space Technologists - Hybrids
  - Majors not traditionally leading to Space Careers need to join with traditional ones

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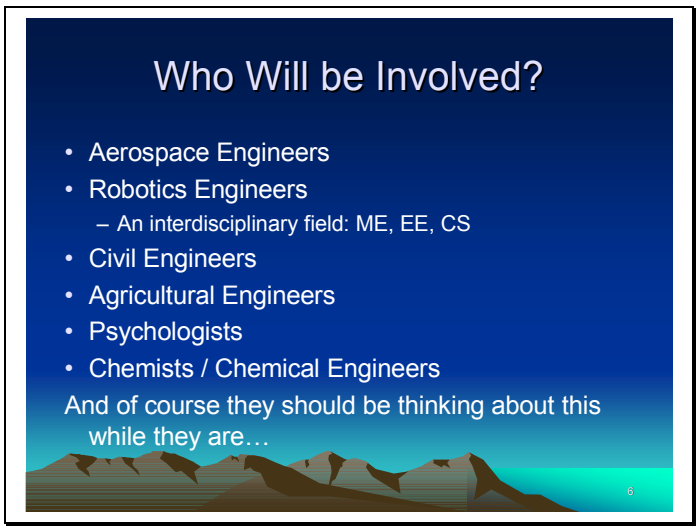
Regolith resources= Metals (some precious), Helium 3 (not found on Earth, fusion reaction fuel), Oxygen (used in rocket fuel), Radiation Shielding (10 meters for protection).

Liquid Oxygen used in rocket fuel- rockets could refuel on the Moon, in space (less weight at lift-off)

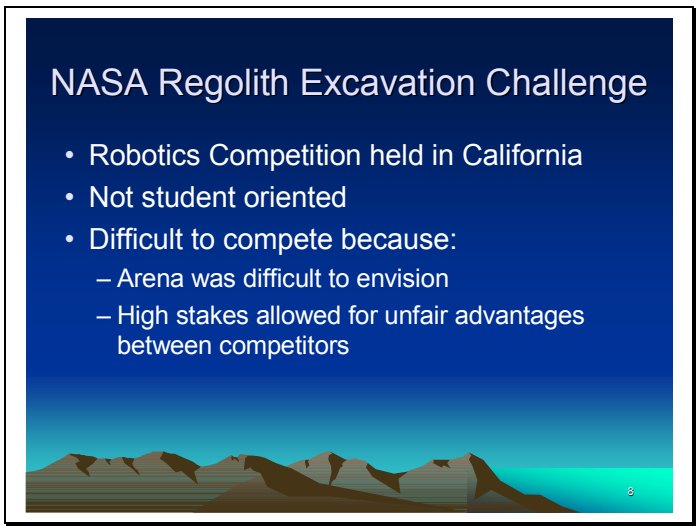
Earth's gravity is 6 times that of the Moon



Mention briefly why each of these fields will now be needed in space

Not a complete list.

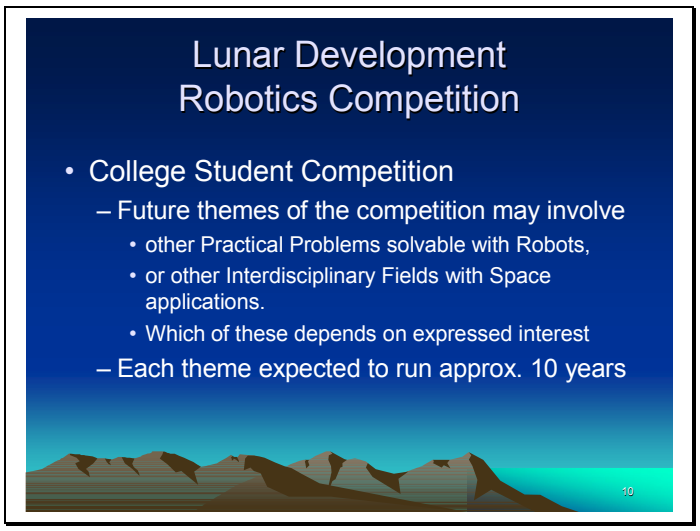
College students could be brought into industry already prepared to face expected problems, if they're exposed to them early



Inspiration for our competition.

Give reasons why good for companies, but not good for universities.

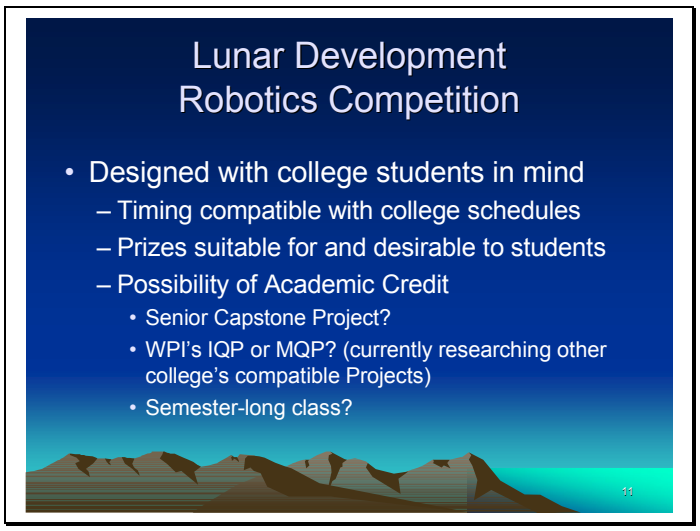
The goal of LDRC is not to develop robots for space, though that will be a positive side effect. The goal is to get students with various Majors to look into Space as a possible career option and to gain experience that will help them to prepare for that career.



Practical problems- as opposed to other educational robotics competitions that seem more sport-like with games.

Our competition is a nice transition from high school robots-for-fun to professional robotics.

Each year, competition builds on one before it, if it was successful. Require open source style because it's an educational format, not a trade secret



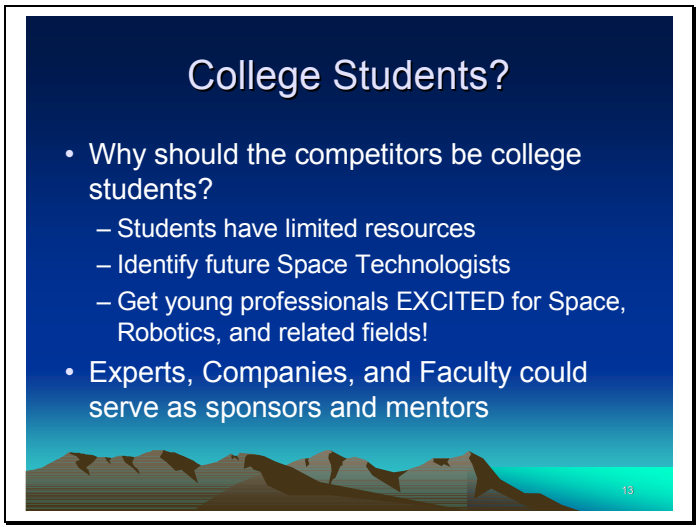
Prizes: cash, scholarships, shiny trophies and/or metals

Will survey college students on different campuses to see how we're doing

Practical Hands-on Experience: Learn about the space environment, Work with students of different Majors,

Robots useable eventually- each round of the competition would build off of the previous one, so it would start with concepts already known and used in space, then move to progressively more advanced tech/problems over the next 10 years.

Awesome, exciting, interdisciplinary, rapidly advancing, innovative, expanding, etc.!



Students have diff. time/money allotment for competitions than Companies or Private Organizations.

Current Generation of Space Technologists could/should pass knowledge on to Next Generation.

…which is why we're here: to present our idea to all of you, get some feedback, and see how much interest there is for a competition of this sort among college students and the AIAA.

Want NASA as sponsor to put up prizes.

Want AIAA sponsorship (impartial, yet knowledgeable third party to be sponsor, oversee, choose location, provide judges, etc.)

Say why it's needed (credibility, $$, space/time, man-power). Explain what is needed from each.

Need college faculty, staff, and/or administration at various universities to house the competition and provide staff, judges, and coaches. Need college students to compete and to let us know what they'd need/want in a college competition. Need Companies and Private Organizations interested in Space and/or Robotics to act as coaches and mentors. We'd also want Companies to let us know what kind of robots or other devices they'd like to see developed for space. And last but certainly not least, we need the aid of Pro Orgs, such as AIAA, and Gov. Agencies, such as NASA, to support us with credibility, prize money, judges, and any other support they're willing to give.

AIAA is national org. with network of Regions and Chapters, useful for spreading the word.

NASA is very well recognized.

Prof. Wilkes said be very explicit when asking for Sponsorships.

Summary

- New Generation of Space Technologists
- Requires a fore-knowledge of other fields and of space environments
- Lunar Development Robotics Competition
  - college student competition
- Would like AIAA sponsorship
- Would like NASA to provide prizes

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QUESTIONS?

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Contact Information

- Justin Barrett
  - jbarrett@wpi.edu
- Celina Webber
  - RaonFire@wpi.edu
- Professor Wilkes
  - jmwilkes@wpi.edu
- Professor Ciaraldi
  - ciaraldi@wpi.edu

Lunar Development Robotics Competition
ldrc@wpi.edu

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Hybrid Space Technologists: Interdisciplinary cooperation, including fields not previously space-oriented

Appendix B: Survey Instrument

The following pages are a printer-friendly version of the survey instrument designed to gauge the interest of potential participants in LDRC. This survey was created using SurveyMonkey.com.

(Note: This survey can also be previewed at the following website without collecting any responses, which is why it says “preview mode=do not use this link for collection” right in the link: <http://www.surveymonkey.com/s.aspx?PREVIEW_MODE=DO_NOT_USE_THIS_LINK_FOR_COLLECTION&sm=ZigXL2Y1aL%2fGOiRTjDLFH%2bUa4mUHV8xq9sOld20HK24%3d>)

Lunar Development Robotics Competition (LDRC)

Impressions

Please answer the following questions to tell us what you think about this Lunar Development Robotics Competition idea.

1. Given what you currently know about this competition (LDRC as described in the attached documents), how interested would you say you personally are in forming a team and competing next year? How interested would you say your institution's professors and other faculty are likely to be? How interested would you say your institution's student body is likely to be?

	no interest at all	very little interest	some interest	moderate interest	great interest
you	○	○	○	○	○
faculty/staff	○	○	○	○	○
students	○	○	○	○	○

2. If your school were to sponsor a team for LDRC, what would be a reasonable/feasible annual budget range (including materials, transportation, accommodations, and other costs) given an anticipated $25,000 - $50,000 first prize?

- ○ $999 or less
- ○ $1,000 – $4,999
- ○ $5,000 - $9,999
- ○ $10,000 - $19,999
- ○ $20,000 - $29,999
- ○ $30,000 - $39,999
- ○ $40,000 or more

3. Have you heard of any of the following competitions prior to taking this survey? Each of these are robotics competitions that have differing college student involvement.

- ☐ FIRST
- ☐ RIC
- ☐ NASA Lunar Regolith Excavation Challenge

4. Do you know of any other competitions similar to LDRC? If you do, please name at least one or two of them:

5. How many interested students do you think there would need to be at your institution in order to form a sufficient team?

Lunar Development Robotics Competition (LDRC)

6. How difficult would it be to form a 6-10 person team for LDRC or a similar competition...

	very difficult	difficult	somewhat difficult	somewhat easy	easy	very easy
If it was available only as a club activity (with no course credit)?	○	○	○	○	○	○
If you could get course credit but it fulfilled no graduation requirements (ie: elective or independent study)?	○	○	○	○	○	○
If you could get course credit for it AND fulfill a graduation requirement?	○	○	○	○	○	○

7. It is recommended that LDRC teams either be multidisciplinary (containing multiple students who each have different majors) or interdisciplinary (each student has skills in more than one major/field/area). How likely do you feel it is for your college to assemble such a team?

	not very likely	not likely	somewhat unlikely	neutral	somewhat likely	likely	very likely
likelihood of multidisciplinary / interdisciplinary teams	○	○	○	○	○	○	○

8. If your institution is unlikely to put together a team for this upcoming academic year (2010-2009), how likely would it be to put together a team for future years (knowing that the intention is for LDRC to run annually for 5 - 10 years)?

	not very likely	not likely	somewhat not likely	neutral	somewhat likely	likely	very likely
likelihood	○	○	○	○	○	○	○

Lunar Development Robotics Competition (LDRC)

University/College Information

Please tell us about your institution. Knowing the resources available to potential participants will allow us to better understand what can be expected of them.

1. Does your school offer the following (or comparable) courses (check all that apply)?

- ☐ Introductory Robotics
- ☐ Advanced Robotics
- ☐ Industrial Robotics
- ☐ Mobile Robotics
- ☐ Space Technologies
- ☐ Lunar Operating Conditions
- ☐ Static Systems
- ☐ Kinematics
- ☐ Dynamic Systems
- ☐ Controls (Mechanical, Electrical)
- ☐ Signals Analysis
- ☐ Digital Logic Design
- ☐ Embedded Computer Systems
- ☐ Programming Design
- ☐ Algorithms
- ☐ Systems Programming
- ☐ Software Engineering
- ☐ Artificial Intelligence

Other course(s) related to Robotics and/or Space (please specify)

2. Our college (check all that apply):

- ☐ has an AIAA student chapter
- ☐ has an IEEE student chapter
- ☐ has an ACM student chapter
- ☐ has an ASME student chapter
- ☐ mentors a FIRST robotics team
- ☐ has a robotics club
- ☐ has a space club
- ☐ has an astronomy club
- ☐ sponsors a team for another robotics competition
- ☐ sponsors a team for another space-oriented competition

3. Please list the undergraduate and graduate majors offered at your school, or supply a link to where they are listed online.

Lunar Development Robotics Competition (LDRC)

Course Information

Please answer the following questions regarding classes, projects, and/or other opportunities to earn credit at your institution.

1. Does your college/university have an obvious mechanism for forming teams to compete in a space-oriented robotics competition like LDRC (such as a club/organization, or capstone/senior/other project)?

- ◯ No
- ◯ Yes

2. If so, is it a...

- ☐ Class
- ☐ Independent Study
- ☐ Club or Professional Organization
- ☐ Capstone Project Program
- ☐ Senior Thesis

Other (please specify)

3. Does your institution require its students to complete a major project of some sort before graduation?

- ◯ No
- ◯ Yes

4. If yes, could they participate in a robotic design competition, such as LDRC, to fulfill this project requirement?

- ◯ No
- ◯ Yes, but only if special permission is granted
- ◯ Yes

5. Would a student be able to get course or independent study credit for participating in a robotic design competition such as LDRC?

- ◯ No
- ◯ Yes, but only if special permission is granted
- ◯ Yes

Lunar Development Robotics Competition (LDRC)

6. Would offering LDRC for credit somehow (either as suggested in the above questions or in some other fashion) change the interest level(s) reported in Question 2 on Page 1? If so, indicate how below. If not, skip this Question.

	no interest at all	very little interest	some interest	moderate interest	great interest
you	○	○	○	○	○
faculty/staff	○	○	○	○	○
students	○	○	○	○	○

Lunar Development Robotics Competition (LDRC)

Demographics

1. What is your gender?

2. Which best describes your current age?

- ◯ less than 18 years of age
- ◯ 18 years or older

3. Which of the following best describes your current status?

Lunar Development Robotics Competition (LDRC)

Demographics (undergraduate)

(If you are not an undergraduate student, please hit the "Previous" button at the bottom of the page and choose a different option.)

1. What is your major?

2. What year are you?

- ◯ Freshman / First year student
- ◯ Sophomore / Second year student
- ◯ Junior / Third year student
- ◯ Senior / Fourth year student
- ◯ Fifth year student

More than 5 years (please indicate how many)

Lunar Development Robotics Competition (LDRC)

Demographics (graduate)

(If you are not a graduate student, please hit the "Previous" button at the bottom of the page and choose a different option.)

1. What is your major?

Page 8

Lunar Development Robotics Competition (LDRC)

Demographics (faculty)

(If you are not faculty at your institution, please hit the "Previous" button at the bottom of the page and choose a different option.)

1. What Department are you in (please do not abbreviate)?

2. Are you a... (check all that apply)

- [ ] Department Head
- [ ] Tenured Professor
- [ ] Full Professor
- [ ] Adjunct Professor
- [ ] Associate Professor
- [ ] Assistant Professor
- [ ] Visiting Professor

Lunar Development Robotics Competition (LDRC)

Final Thoughts

1. Given what you now know about LDRC and your institution, please rate the following statements, indicating to what degree you agree/disagree with them:

	strongly disagree	disagree	somewhat disagree	neutral	somewhat agree	agree	strongly agree
I am interested in being on a team (if a student) or coaching a team (if faculty).	○	○	○	○	○	○	○
I know of other faculty/staff members at this institution who would be interested in coaching a team.	○	○	○	○	○	○	○
This competition (LDRC) would be a significant educational opportunity.	○	○	○	○	○	○	○
The students at this institution would be interested in participating in this competition (at least enough students to form a team).	○	○	○	○	○	○	○

2. Please use the box below to leave any comments, suggestions, or questions you may have about LDRC or this survey.

Lunar Development Robotics Competition (LDRC)

Contact Information (optional)

We would like to remind you that all your answers are confidential. If you choose to supply us with your contact info, it will only be used to give you additional general information about LDRC as it develops.

1. If you or someone else at your college would like more information about LDRC, please provide some of the following information:

Name:

College/University:

Address:

Address 2:

City/Town:

State:

ZIP/Postal Code:

Email Address:

Phone Number:

If there is someone else at your institution that you feel would also be interested in a space-oriented robotics competition, please feel free to pass this survey along to them (including the Informed Consent Form and all attached documents).

Lunar Development Robotics Competition (LDRC)

Survey Complete

Thank you for your time! Your input is very important to us.

If you supplied us with your contact information, you will be hearing from us as soon as the details of this Lunar Development Robotics Competition have been worked out.

If you have any questions or comments regarding this survey or LDRC, feel free to contact us at ldrc@wpi.edu and we will be sure to get back to you shortly.

Have a wonderful day,
~the LDRC Team
ldrc@wpi.edu

Appendix C: IRB Exemption Letter

WPI

Department of
Social Science
and Policy Studies

100 Institute Road
Worcester, MA 01609-2280, USA
508-831-5296, Fax 508-831-5896
www.wpi.edu

27 March 2009
File: 2009-EX-047

Worcester Polytechnic Institute
100 Institute Road
Worcester, MA 01609

Re: IRB Application for Exemption 2009-EX-047: "Lunar Development Robotics Competition"

Dear Professor Wilkes,

The WPI Institutional Review Committee (IRB) has reviewed the materials submitted in regards to the above mentioned study and has determined that this research is exempt from further IRB review and supervision under 45 CFR 46.101(b)(2): "Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation."

This exemption covers any research and data collected under your protocol from 27 March 2009 until 26 March 2011, unless terminated sooner (in writing) by yourself or the WPI IRB. This approval becomes immediately null and void if this project receives any federal sponsorship and work on this study must cease until review and approval by New England IRB. Amendments or changes to the research that might alter this specific exemption must be submitted to the WPI IRB for review and may require a full IRB application in order for the research to continue.

Please contact the undersigned if you have any questions about the terms of this exemption.

Thank you for your cooperation with the WPI IRB.

Sincerely,

Kent Rissmiller
WPI IRB Chair

Appendix D: RASC-AL Contest Description

The following was taken directly from http://www.nianet.org/rascal/ on 2 June, 2009.

RASC-AL, Revolutionary Aerospace Systems Concepts Academic Linkage, is sponsored by NASA and National Institute of Aerospace, or NIA, and is a design project competition aimed at university-level engineering students. RASC-AL was formed to allow engineering students a chance to integrate their academics into real life learning. RASC-AL is announced in September and concludes with a competition between the different teams in June.

RASC-AL contest challenges university students to think about what sorts of conditions astronauts will face when we return to the moon, then design projects that may become part of actual lunar exploration.

"As NASA faces the challenges of going back to the moon, it's important to stimulate the creativity of the next generation of engineers," said Pat Troutman, senior systems analyst at NASA's Langley Research Center in Hampton, Va. "The RASC-AL contest gives engineering students a unique opportunity to combine their academic studies with real life learning and come up with design solutions."

Student teams must submit a summary of and an outreach plan for their proposed projects by February 6, 2009. Their work must be based on one of four themes: outpost to settlement, initial lunar outpost, bringing the world along with virtual exploration and novel approaches to increase sample return from the moon. The RASC-AL Steering Committee of NASA and industry experts will evaluate the proposals and select as many as ten undergraduate and five graduate teams to compete against each other at a forum next June in Florida.

Appendix E: ABLE Abstract

The following is the abstract for the project entitled Advanced Ballistic Lunar Explorer (ABLE) by Daniel Asselin, David Beavers, David Cancel, Stephen Jakubowski, Ashish Palooparambil, and Casey Rogan, along with their advisor Professor John Blandino.

Advisor: Prof. John Blandino

Undergraduate Students: Daniel Asselin, David Beavers, David Cancel, Stephen Jakubowski, Ashish Palooparambil, Casey Rogan

Affiliation: Worcester Polytechnic Institute

Project Title: Advanced Ballistic Lunar Explorer (ABLE)

NASA is planning the establishment of a lunar outpost to be operational by the end of the next decade. To support an extended presence on the Moon, it will be necessary to have a reliable, rapid, and cost-effective means of scouting for new settlement locations and searching for natural resources in areas far removed from the outpost location. The design for a ballistic "hopper" vehicle is presented. The hopper would be able to traverse, via a series of suborbital trajectories, large distances and terrain that would be otherwise impassable for a wheeled vehicle. Vehicles of this type would be the cornerstone of a novel lunar transportation architecture. Such hopper vehicles have been proposed for Mars exploration as well [1], and use on the Moon could serve as a critical technology demonstration in support of NASA's long-term exploration goals.

To limit the requirement for an extensive logistics supply chain from Earth, a significant fraction of the propellants used for the hopper vehicle will be produced in-situ from lunar resources. Previous studies have already demonstrated the possibility of extracting oxygen, magnesium, aluminum, and other potential propellants from regolith [2,3], and this capability is a key element of any long-duration settlement on the Moon. One of the areas investigated in the trade-study is the amount of propellant that could be produced onboard the hopper versus that which must be produced at the main outpost.

In addition to the propellant-production hardware, the hopper will be able to carry a scientific payload, which could include a deployable rover. NASA already has significant

experience with planetary rovers, such as the successful Sojourner and Mars Exploration rovers, and this investment could be leveraged for this proposed concept. While the hopper is processing lunar regolith for refueling at a remote location, the rover could carry out scientific investigations. One goal of the design study will be to budget sufficient mass, volume, and power to accommodate a MER-class rover payload. Power for the hopper will be supplied using existing solar array technology.

Some of the key Figures-of-Merit used in this study are 1) the hopper's ability to traverse long distances without the need for refueling at a settlement site, 2) minimizing the amount of propellant which needs to be supplied from earth, 3) the ability to traverse hazardous terrain (i.e. achievable altitude), and 4) maximizing use of technologies to be developed as part of the Constellation architecture. Public interaction will be encouraged through educational outreach activities coordinated with the local chapter of the AIAA.

References

[1] Sercel, J.C., Blandino, J.J., and Wood K.L. The Ballistic Mars Hopper: An Alternative Mars Mobility Concept. AIAA/SAE/ASME/ASEE 23rd Joint Propulsion Conference, 29 June-2 July 1987, San Diego, California.

[2] Meyer, M.L. Design Issues for Lunar In Situ Aluminum/Oxygen Propellant Rocket Engines. AIAA Aerospace Design Conference, 3-6 February 1992, Irvine, California.

[3] Taylor, L.A. Production of Oxygen on the Moon: Which Processes are Best and Why. AIAA Space Programs and Technology Conference, 24-27 March 1992, Huntsville, Alabama.