THE SOONER LUNAR SCHOONER: LUNAR ENGINEERING EDUCATION

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ABSTRACT

The Sooner Lunar Schooner is a multi-disciplinary ongoing project at the University of Oklahoma to plan, design, prototype, cost and (when funds become available) build/contract and fly a robotic mission to the Moon. The goal of the flight will be to explore a small section of the Moon; conduct a materials analysis of the materials left there by an Apollo mission thirty years earlier; and to perform a selenographic survey of areas that were too distant or considered too dangerous to be done by the Apollo crew. The goal of the Sooner Lunar Schooner Project is to improve the science and engineering educations of the hundreds of undergraduate and graduate students working on the project. The participants, while primarily from engineering and physics, will also include representatives from business, art, journalism, law and education. This project ties together numerous existing research programs at the University, and provides a framework for the creation of many new research proposals. The authors were excited and motivated by the Apollo missions to the Moon. When we asked what we could do to similarly motivate students we realized that nothing is as exciting as going to the Moon. The students seem to agree.

MOTIVATION FOR MULTIDISCIPLINARY ENGINEERING PROJECTS

With the exception of a few labs and a semester capstone class, the majority of engineering classes are still taught in a traditional lecture format. This format of education is sufficient for many students, but is by no means compatible with all students' learning styles. In fields such as engineering, a traditional lecture format fails to give students a realistic feel as to what most working engineers actually do.

Working engineers who manage to avoid management chores spend a large portion of their time working on projects. Often times this work involves actual hands-on time with hardware or software, or with the production process. The traditional lecture format of education fails to give proportional time to these activities. Because of this, students are not as prepared for actual engineering work as they are for taking engineering exams. More importantly, for many students, a traditional engineering education lacks the attraction of actual engineering work. As a result, many engineering students switch majors or drop out of the program because their educational experiences did not match with their expectations of what it was to do engineering. Sometimes this is due to misguided expectations, but often the students' expectations are correct, and their disappointment is due to an actual disconnect between the educational and the engineering processes.

In 1998, the College of Engineering at the University of Oklahoma (OU) started a study to explore making their curricula more project-based, in order to address the concerns above (Shirley et al. 2002). Project based - or experience based - engineering is widely recognized as a preferred method for not only interesting students in engineering, but in improving their learning (Kolb 1984, Smith 2000). Several options were explored including adding several project-based courses and even a project track for the various majors. The different options all required projects with the following characteristics:

1. Multi-year duration
2. Students could participate at all levels of university education

3. Projects involved multiple disciplines
4. Students could move through the project as their education progressed
5. Projects would attract and engage students
6. Projects would be able to attract funding and become self supporting
7. Projects would advance the research interests and reputation of OU.

The Sooner Lunar Schooner (SLS) project was initiated to address these educational goals and requirements[1]. The SLS is being implemented as a flexible series of courses, capstone projects, and research directions that are synergistically linked and build upon one another. For the moment, all elements of SLS are in the OU College of Engineering. The authors are currently working with members of the College of Arts and Sciences in order to get appropriate projects in Physics & Astronomy, Business, Law, Journalism, etc. underway as well.

ORIGINS

During the Summer of 1999, the Summer session of the International Space University (ISU) did a design project on extra-planetary human exploration. One of the key precursor missions proposed in this study was to have a Lunar rover race (ISU-SSP 1999). The race was a refinement of ESA's EuroMoon 2000 project which proposed having several rovers circumnavigate the Aitken basin at the Lunar South pole. These were the latest in a series of proposals to do a variety of robotic missions on the Moon in the wake of the popularity of the Mars Pathfinder mission.

Another project with similar origins was Blastoff! Corporation's *L1: Return to Apollo* mission. Blastoff! was a spinoff company from Idealab. The company's mission was to do entertainment space mission – real missions that would pay for themselves through the sales of advertising, media content, action figures, etc. Blastoff! differed from other companies espousing similar goals (e.g., LunaCorp) in that it was decided not to advertise until it was well into phase C & D of the mission, and Blastoff!'s first mission was fully funded[2]. During 2000, a team of about thirty engineers created a detailed mission design, including several design iterations of spacecraft and rovers. A significant amount of prototype hardware was also created. Unfortunately, changes in the US stockmarket caused Blastoff! to cease operations in early 2001, but the lessons learned during the design and prototype studies have not been lost.

The authors bring the above experiences and a wealth of other practical experience in planetary mission technology and planning, (e.g. (Miller et al. 2003, 1992, Shirley 1998, Hougen et al. 2000)). These experiences have led to the creation of several related courses and programs.

CURRENT & FUTURE CLASSES

The first specific classes for the Sooner Lunar Schooner started in the Spring of 2001, though several classes done in the two years prior directly reenforced the SLS missions. In addition to normally scheduled undergraduate and graduate courses tied to SLS, we are fleshing out the SLS program by making use of engineering outreach that is aimed at K-12 grades and run by both OU and affiliated organizations. The SLS project is a large project. As such, we are giving students hands-on experience in both technical and management domains. Our courses reflect that.

K-12 Outreach Programs

There is ample evidence, for instance (Nanny et al. 1999, Mooney & Taubach 2002, Stein 2002), that project-based learning is effective for all ages. SLS is working with the organizers of Botball (KIPR 2002, Miller & Stein 2001), a robotics education program that has middle and high school students build and program teams of autonomous robots. Botball events are held throughout the USA. As part of the Botball program, student teams create websites after researching a particular robotics problem. The research problem is set by the Botball staff. The last few years have had topics dealing with Lunar exploration of the South Pole, Lunar missions to Apollo sites, etc.

The authors are also involved with the Oklahoma Summer Academy Program. The topic of the authors' academy is the robotic exploration of planetary surfaces. This is an outgrowth of a major national education initiative, the Mars Millennium Project (US-DoEd 2000). These programs work with area high school students during a multi-week summer program on a particular topic.

[1] The SLS was also started because the authors and other members of the College of Engineering have been looking for any excuse to justify their interest in working on a Lunar exploration project.

[2] Unfortunately, the mission was backed with ≈$70M in Idealab stock, which by early 2001 had lost most of its value.

Technology Courses

OU currently offers a variety of relevant technology classes covering everything from the basics of Lunar geology, to the design of satellite relay telecom systems. We have also started introducing project classes that feed directly into SLS. One such course on satellite control was introduced in 2001 involved the construction and control of a spacecraft testbed that used a compressed gas thruster system and floated on an air-bearing table.

Another technology course recently introduced is *Introduction to Intelligent Robotics*, a Computer Science course aimed at teaching graduate and undergraduate students the fundamentals of modern mobile robotics using the Sooner Lunar Schooner as both an organizing principle and a motivating factor. On the first day of class, students were asked to brainstorm about uses for robotics technology, asked what activities they would see robots accomplish in next 10 years, then introduced to the SLS concept. The interest level in the class rose visibly as students realized that the work they did could influence such a high-profile mission. We immediately set to work, jointly designing everything from the team structure that would be used by students for the class projects through to the last of the four team projects.

The course utilized lecture and discussion sessions, independent reading, and team projects to convey the material to the students. Student evaluation was carried out through examinations and appraisal of the team projects—students were required to demonstrate their robots, write up their experiences, and give presentations to the class. For the graduate version of the class, students were also required to complete a larger writing project.

The team projects built progressively on one another. Project 0 introduced the students to the basis of intelligent robotics—tying sensing to action —and the hardware and software tools that would be used throughout the course. To complete project 0, students needed to have a robot that could carry out a predetermined set of actions in a known environment (moving back and forth between two barriers 10 times). Nonetheless, their robots needed sensing to compensate the inability of the robot platforms to carry out their operations with great precision.

Project 1 required that students build robots that could act in a highly uncertain environment. The uncertainty in this environment came from "noise" in both sensing and acting as well as the fact that the students did not know the exact layout of the objects in the test environment before the demonstrations began. The test environment was a very rough simulation of a lunar surface—a bed of gravel with rocks scattered about. Moreover, the robot needed to engage in several different activities at appropriate and not necessarily sequential times. The general task was to move from a base station, search the environment, find a lighted target, and bring it back to the base station.

While project 1 could be accomplished well with purely reactive robots, project 2 required deliberation as well as reaction to succeed. In this project, the robots were provided with some information before they left their base stations. In particular, they were given the coordinates of some of the rocks and a target. Other rocks and additional targets were also located in the test environment. To succeed, the robots were required to carry out their search and retrieval task efficiently.

Finally, project 3 brought teams of students together for a multi-robot task—mapping the locations of the rocks in the environment. Again, efficiency was an issue and robots needed to act both deliberatively and reactively.

The graduate writing project had four components: (1) doing a literature search, (2) writing summaries of appropriate technical papers found, (3) making comparisons between these papers, and (4) evaluating the appropriateness of the methods discussed for a particular task. The topic for the technical papers reviews was software control architectures for multi-robot systems, including distributed robotic architectures and architectures for swarm systems. The application task was a lunar mission to explore lava tubes as potential habitation sites for a lunar colony.

Overall student reaction to this course was quite positive, as reflected in anonymous student evaluations of the course. Introduction to Intelligent Robotics was introduced into the Computer Science curriculum as a joint undergraduate seminar and graduate special topics course in Spring Semester 2002 and will be offered again this same way in Spring Semester of 2003. It is anticipated that it will become a regular part of the curriculum beginning in 2004.

More information is available at the class website (Hougen 2002).

Management Courses

Managing Creativity is a course based on the author's (Shirley) 35 years of experience in a variety of creative enterprises, including management of NASA's $150M per year Mars Exploration Program and of the Pathfinder microrover. The class also builds on the NASA Systems Engineering process which was developed by a team, led by the author, in the early 1990s.

Engineering students need skills in communication, teamwork, understanding of business processes, and awareness of and appreciation for other cultures which yields an ability to work in global enterprises. The Sooner Lunar

Schooner concept provides an excellent platform for educating engineers in all these aspects.

Harnessing collective creativity to produce useful, saleable and innovative products can be made a lot more effective by using a process that specifically addresses all the phases of a product life cycle, and all the tools available to create and bring the product to reality. Such a creative process can be visualized as a system of interrelated elements, as shown in Figure 1, below. The elements around the ellipse in Figure correspond to phases in a product lifecycle, but the double-headed arrows indicate that they can't just proceed in a step-by-step process. They must continually interact and each element affects, and is affected by, the others. More details of the Managing Creativity course may be found in (Shirley 2002).

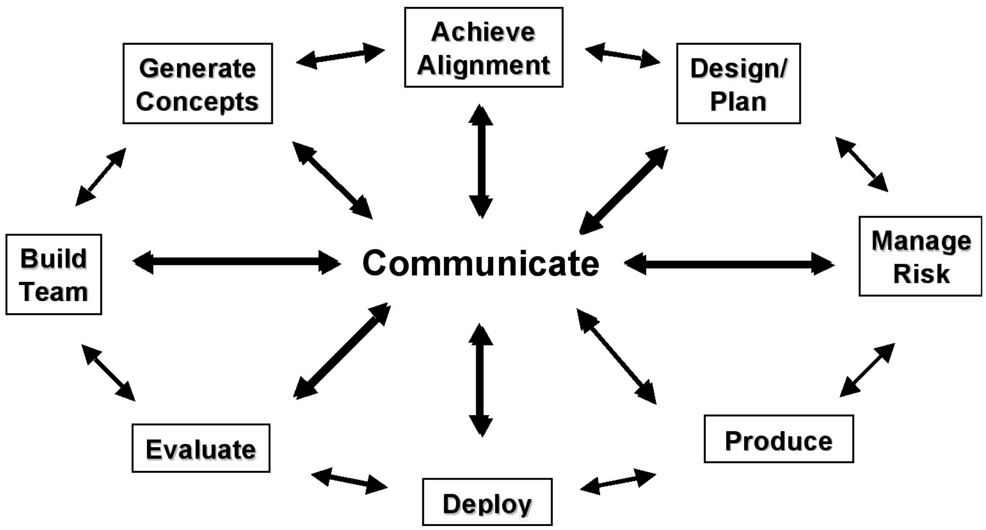

Fig. 1. The creative process

Mission Courses

To help focus the various courses and research going on related to SLS, in the Fall of 2002, a mission design course was created to create an SLS mission scenario, top level requirements for the mission, and second level requirements for the robotic payload.

The final requirements document that was created during the course contains the SLS mission definition:

> The Sooner Lunar Schooner mission of the University of Oklahoma will be to land multiple robotic vehicles on the surface of the moon. The robots will land near the Apollo 17 site and explore the surrounding environment and spacecraft. One robot will be specifically designed to carry out tasks of scientific interest that involve the Apollo 17 LM structure. The knowledge gained from long-term exposure (30+ years) to structural components is invaluable. A second robot will be sent to the Lunakhod site (approx. 150+ km) to document and photograph the environment. This mission also will help provide evidence that a long range small scale robotic vehicle can accomplish its objectives in a timely manner with a high probability of success.

Specific mission goals are to land robotic vehicles on the moon and carry out the following operations in one lunar day:

- To use robots with which the public can identify, and to use 3^{rd} person perspective wherever possible,
- To break total distance traverse record on the moon in one lunar day,
- To navigate a path and locate the Lunakhod robot,
- To do material analysis on the Apollo 17 LM, and
- To compare the current state of the LM materials with those documented in the detailed materials inventory created before the Apollo 17 launch.

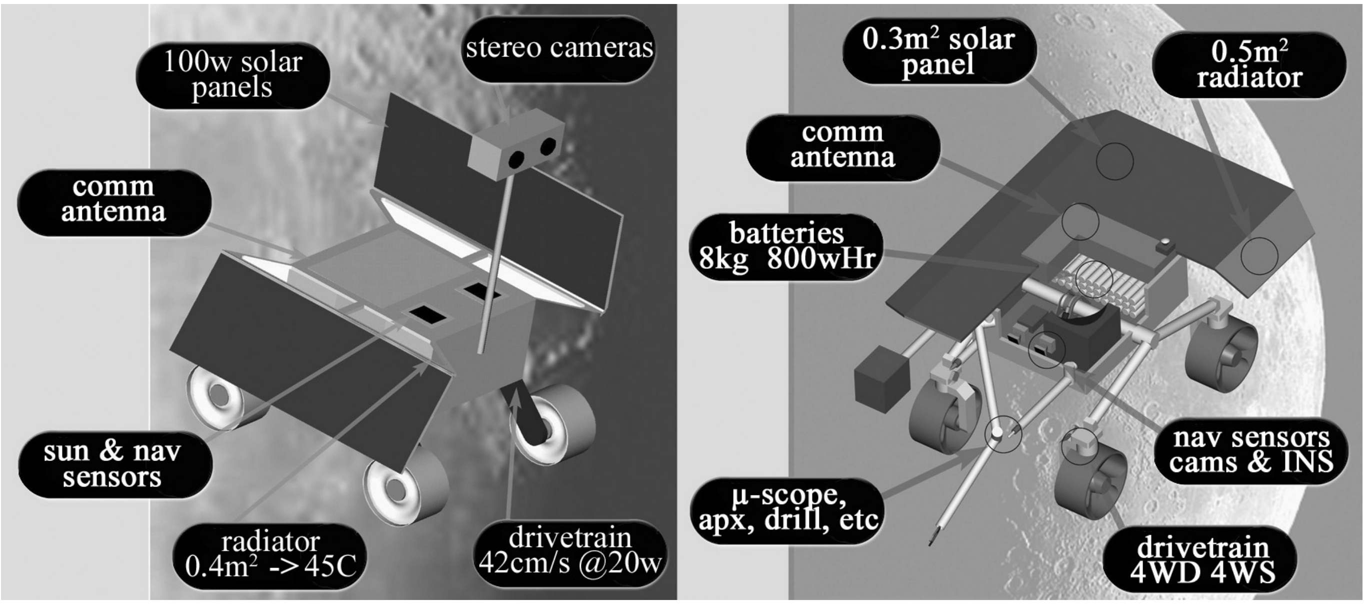

Fig. 2. The lunar long range and science rovers

In addition to the mission structure, requirements documents for each of the robots and their subsystems have been created, along with detailed subsystem descriptions. Models and configuration drawings of the science rover and the long range rover (Figure 2) have been created (Roman et al. 2003).

EVALUATION

There are two ways to evaluate this project. The most obvious is to see what impact this project has on future Lunar missions. If ten years from now the OU flag is on the Moon then a certain level of project success has occurred.

From an educational standpoint, we will evaluate this project based on exit surveys of students who have participated in the SLS classes and compare them to similarly qualified students who have not. We will be looking at their academic performance their evaluations of courses as to utility and enjoyment and their future career goals – along with their ability to achieve those goals. Future refinement of the evaluation criteria and the results of that evaluation will be periodically posted on the SLS website: `www.ou.edu/sls`.

CONCLUSIONS

Lunar missions provide a unique opportunity to embody key engineering principles and skills. Solar power, thermal control, material oxidation, navigation, mobility etc. are both more pure and more challenging to deal with in the Lunar environment. SLS also allows students and faculty to work in small teams and as part of a large team and large project – situations not common in the academic environment. The SLS gives students and researchers a chance to work on these issues while addressing a challenging and highly motivating problem. University development and the whims of alumni hold out the hope for actually accomplishing something amazing in the end.

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