PROPOSAL TO THE HEDS-UP PROGRAM

Lunar and Planetary Institute
Houston, Texas

Submitted by:
Dr. Robert D. Knecht
Colorado School of Mines
(303-273-3592)

Resources requested: Travel grants for 2 students and 1 faculty member to attend the HEDS-UP Forum, to be held May 2-4, 2000, in Houston, Texas

Participants in study: 411 First-Year Engineering students; 16 CSM Faculty members.

Topic: Excavation of Martian Regolith for Resource Extraction

Client: Dr. Michael B. Duke

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INTRODUCTION:

The Colorado School of Mines (CSM) provides quality education, research and outreach in all areas of science and engineering. CSM's undergraduate students are involved in some of today's most advanced fields of science, economics, and engineering including materials, computing, energy development and conservation, and environmental science and engineering. Graduate programs in science, economics, and engineering provide students with educational and research opportunities in materials, energy, minerals, environmental science and engineering, and the production and utilization of natural resources. Balancing resource availability and environmental integrity is a primary focus for many of CSM's graduate programs. In 1989, CSM established the Center for Space Mining, in recognition of the potential importance of the discipline in the economic development of space. In 1997, the Center for Space Mining entered into a cooperative agreement with the Johnson Space Center, which provides for exchanges of information between the two organizations. CSM is now renewing its commitment to the field of space mining and resource development and intends to strengthen its participation in exploration programs. Outside the Center for Space Mining, faculty members are participating with the Jet Propulsion Laboratory in the design of deep drilling techniques and the Center for Commercial Applications of Combustion in Space is actively developing experiments to be flown on the International Space Station.

DESIGN ENGINEERING PRACTICES INTRODUCTORY COURSE SEQUENCE (EPICS):

The Design (EPICS) program builds a student's confidence to apply fundamental concepts and to resolve open-ended problems. This course emphasizes application of technical, team, and communication skills, which serve as a basis for a design engineering curriculum. Learning is enhanced through "hands on" experiences and exercises applying these skills. Teams assess engineering ethics, group dynamics and time management with respect to decision making. The course emphasizes written technical communications and oral presentations. The Design (EPICS) program is required for all undergraduate engineering students at CSM.

Engineering design is a complex, interactive, and creative decision-making process that evolves as the design team synthesizes information, skills and values to resolve an open-ended problem. To help students become more skilled at this process, we have them learn through practice. The centerpiece of each Design sequence, therefore, is an open-ended problem that students must work in teams to solve. Although the instructor's primary role is to apprentice students through their difficulties, they also give explicit instruction or information in carefully selected topics.

"Hands-on" application of these skills through the project facilitates students' learning specifically of AutoCad and other computer-aided design software applications.

Skills are taught using a small group mentoring approach with a few lectures to present formal instruction. A professor meets with 20-25 students, three times a week, two hours per meeting. The professor's responsibility is to guide the students through their project, and help them to see how the pieces of the course fit together in their practice of design (see Figure 1). This is a student's first experience with intensive team responsibilities at CSM. As such we schedule formal exercises/lectures that analyze these responsibilities and give the student a framework in which to hone their interpersonal skills. These exercises have them practice team roles (leader, recorder, monitor, etc.), have them practice reflective evaluation (where does our team work well? Where could we do better next time?), and have them focus on values and ethics related to their project. The principle honing of teamwork skills will come through practice and faculty mentoring.

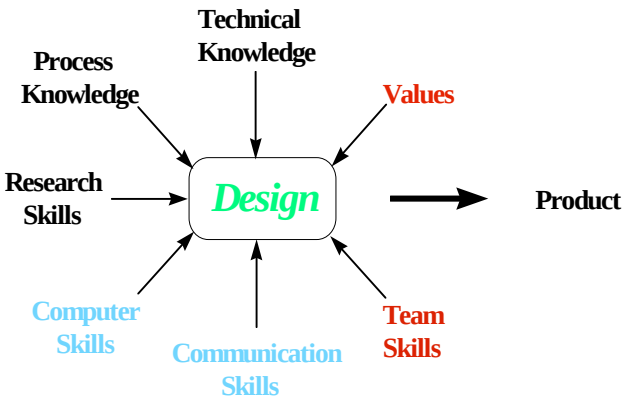

Figure 1: **Theme for Design Stem Sequence**

In the Fall of 1999, 411 Freshmen will be enrolled in EPICS. They will be divided into 16 sections, each of 25 students, each under the direction of a faculty member. Each section will be further divided into 5 design teams of 5 students each.

CSM PROPOSAL TO HEDS-UP:

We have adopted a space exploration topic for our freshman design study this semester. Dr. Michael B. Duke, of the HEDS-UP program suggested the problem. The students will address the problem of excavating Martian regolith with the intention of extracting its water by baking in a furnace. The problem description is provided in the next section.

Dr. Robert D. Knecht coordinates the EPICS program. The faculty members who will lead sections include:

- Professor Donna Carlon
- Dr. John Golden
- Dr. Greg Holden
- Dr. Heidi Loshbaugh
- Dr. Carl Mitcham
- Professor Ted Smathers
- Dr. Chet Van Tyne

Dr. Dean Dickerhoof
Professor Lynne Golden
Professor Phil Kreiker
Dr. Barbara McKinney
Dr. Todd Ruskell
Dr. Danelle Thompson
Dr. Hengren Xia

Dr. Duke has agreed to serve as "client" for these studies. He will make an initial presentation of the problem and thereafter be available from time to time and by electronic mail to answer student's questions. He will participate in the final presentation of team reports.

THE DESIGN PROBLEM:
Excavation of Martian Regolith for Resource Extraction
Dr. Duke provided the following design problem selected for this semester.

The human exploration of Mars is just on the edge of technological feasibility, but currently would cost more than most people would think reasonable and would be risky for the crew. One way to reduce cost and risk is by making use of the resources on Mars to reduce the amount of material that must be transported to Mars (lower cost) and pre-placement of reserves of some materials (particularly rocket propellant) before the humans arrive (lower risk). A good deal of research has been undertaken on the problem of producing methane and oxygen from the Martian atmosphere, but hydrogen has to be taken to Mars because neither hydrogen nor water is present in the Martian atmosphere in high enough abundance to make it feasible to use. There is a ubiquitous source of water on Mars, the soil (called the regolith), which is thought to contain 1% to 4% water, which can be released by heating the soil to about 500°C. Digging up the soil and transporting it to the reactor is a problem. Whereas digging up and moving soil on Earth is not technologically difficult, doing the same on Mars faces a number of problems. The design of a suitable system would appear to constitute a very suitable problem for an EPICS class, because it involves using processes familiar on Earth, but adapted to environmental conditions on Mars.

A useful system should meet the following requirements:

Requirement	***Rationale***
Excavate granular material from the surface down to 10 cm – 20 cm	*Dig up soil material*
Avoid surface rocks	*Reduce hazards to excavator*
Discard rocks > 1 mm diameter	*Water is in finer-grained materials; avoid heating large fragments with little water*
Transport material from excavation site to reactor. Maximum distance is 20 meters.	*Provide sufficient material to meet requirement for water*
Deliver soil to reactor input hopper	*Deliver soil to reactor*
Operate for 8 hours a day under Mars ambient environmental conditions	*Operates only from the equivalent of 8 AM to 4 PM, when maximum sunlight is available*
Operate continuously for 500 days	*Mission duration*
On board maintenance and repair only	*Maintenance and repair facilities not available*
Operate semi-autonomously	*No real time communication available; instructions from Earth can be provided only once a day*
Provide sufficient power for excavation and transportation	*Power is required*
Mass of system less than 20 kg	*Suitable for testing on Mars on a small exploration mission; Later, this could be scaled up for human exploration missions.*
Capable of delivering its own mass of soil to the reactor in one hour.	*Meet total water requirements*

Several subsystems would be required, including the mechanical subsystem, power supply subsystem, and the automation and control subsystem. Some of the requirements may be incompatible. Those incompatibilities should be identified and requirements negotiated in an organized fashion (what NASA calls a "change board." I will provide references describing the surface environment of Mars, including morphology and rock distribution, temperatures and pressures, soil composition and properties, and other relevant environmental information. I will also provide information on NASA's planning for both scientific and human exploration of Mars.

This problem is a very good one for the students, because it is open ended, in that any number of possible solutions can be identified, and because the performance criteria are simply stated. This gives the student the introduction to a real design problem, as might be stated by a customer or client, and allows the team to organize and conduct the research that is needed to address the problem with reasonable efficiency. The problem itself is interesting, so should be attractive to students, and it is within the scope of the professional expectations of many of the students.

OUTREACH:

At CSM, this project is inherently one of outreach, because few of the students that will be participating will have considered problems of space exploration relevant to their experience at CSM. Thus, 411 entering freshmen students will be exposed to concepts of space exploration, what we have learned about Mars, and what some of the interesting problems to be approached might be. In addition, 16 faculty members, who are generally not participating in NASA-related activities, will be exposed to the problem area and to new information from space exploration.

Within CSM, there are also opportunities for outreach to students and faculty. Currently, the Center for Space Mining has access to display cases in the school's library. As part of the EPICS design class, we hope to gain access to miniaturized automated elements through the LEGO Corporation, which might be used by the students to construct operating models. These models may be incorporated with other materials in the Center for Space Mining's display.

For outreach beyond CSM, we will investigate the possibility of involving EPICS students in a "Space Day" at CSM, to be held in the spring of 2000. This would be an open house, where visitors could see displays that would emphasize the CSM's space projects. This could be a place where students from the EPICS class could display the results of their class work.

Finally, it is hoped that the topic selected may become a research topic at CSM for advanced EPICS courses.

PARTICIPATION IN THE HEDS-UP FORUM

CSM proposes that the team selected from this internal competition will be sent, along with one of the faculty members, to participate in the HEDS-UP Forum next May. If HEDS-UP can provide funding for only a portion of the team to travel to Houston, CSM and the EPICS program will strive to obtain resources to send the rest of the team to Houston as well. We will structure the course so that the students will prepare a brief report of their project in the format requested by the HEDS-UP Forum.