Engineering Design Through
The Colorado Space Grant DemoSat Project

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Abstract – The Spring 2003 EPICS Challenge, sponsored by the Colorado Space Grant Consortium, exemplified the “hands-on” experiences that enabled students to practice engineering design. The mission of the project was to measure atmospheric conditions on a high altitude balloon flight that created some tough and challenging design issues for the teams. The construction phase focused on building the satellites, including soldering and foam core construction clinics. The project ended with successful conclusions illustrating the operability of overall structural design, functional electronics, and a classical pressure sensor as well as satisfied team members.

Index Terms – atmospheric satellites, DemoSat, first-year design, NASA,

PROJECT DEVELOPMENT

The Design (EPICS) program continually evolves into a unique engineering design program featuring a project-based, client-sponsored learning experience. The program structure focuses on opportunities to practice (apprenticeship) discovery, exploratory, experiential and application learning in an “as needed” and “hands-on” experience. The curriculum for the course tackles a variety of processes required to address the issues associated with complex problem solving. Students practice decision making with uncertainty through an authentic project sponsored by a client. The constraints (specification) of the project accentuate an engineering approach in which the team identifies the best solution within the time and budget constraints of the project.

We describe the engineering design method as an iterative sequence of discrete segments. Adapted from Wales, Nardi and Stager [1], these segments, illustrated in Figure 1, characterize two phases of design activities and conform to two modes of thinking. We observe a shift in emphasis from creative thinking to critical thinking as the process moves from identifying the needs to implementing the design. Teams focused on exercises to identify needs, define options, develop specifications, and gather data are expected to utilize creative thinking. The team prepares a proposal (design plan) for the client to describe the proposed solution and strategy. While analyzing their results, team members use graphical and analytical routines to assure accuracy and to assess the quality of various aspects of their design. A sound grounding in sociologic, economic, aesthetic, legal and ethical considerations needs to be included in the process.
Implement design – The team determines which possible solutions are most likely to solve the problem. The decision is based on analysis (separating the solution alternatives into smaller elements which can be judged using available information), synthesis (combining appropriate solution elements into larger, more detailed solutions), and evaluation (judging which solution best satisfies the goal and objectives within the constraints of the problem).

Design (EPICS) I is often a student’s first exposure to a complex problem that requires a team to work together. Delivering a quality product in a timely fashion requires an effective team effort. The objective of the teamwork component is to explore the individual role of team members with an emphasis on meeting deadlines. All members must take seriously their contribution to the team. The focus of teamwork for these first-year students, therefore, centers on the role that each team member assumes during the project. Roles are not limited to technical expertise but encompass several areas critical to the project:

- Technical (sketching, writing, engineering problem solving, etc.)
- Management (facilitator, archivist, liaison, etc.)
- Behavioral (task, team – functions governed by Eberhardt’s [2] work)

We encourage teams to rotate management roles allowing each team member an opportunity to develop skills required to lead or manage the team.

Team Leader: The team leader is responsible for project management for the team. As the manager, the leader needs to balance requirements for producing a quality product (management) and satisfying team members (leadership). Often this role changes as the needs of the project changes. We see a shift in the leadership as team activities move from the creative to the critical phase.

Archivist: The archivist documents team discussions and activities. These activities include processes, decisions, and action items. This role assumes responsibility for maintaining a flow of information to support and enhance the team’s work.

Facilitator: The facilitator ensures a steady flow of communication and that all team members contribute. This role entails attention to time factors and the need for decisions.

Liaison: The liaison interfaces with those external to the team (clients, mentors, other teams, etc.) This role follows up on requests both from the team and external parties. The liaison transfers data and information to the archivist.

The National Training Laboratory for Behavioral Studies developed a method for describing team success based on a balance of task and team functions. These functions, summarized in Table I, initially developed by Benne and Sheats [3] have been refined over the years by Schein [4] and Eberhardt [2] as training instruments for training team dynamics. Eberhardt [4] taught observers to record behaviors they saw during problem-solving discussions, and then provide feedback to team members. Jones [5] observed that a balance of task and team roles play a key role in the performance of the team. He noted that team members relate to behaviors more easily than to who assumes what role.

<table>
<thead>
<tr>
<th>Task Functions</th>
<th>Team Functions</th>
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<tbody>
<tr>
<td>Proposing goals or actions</td>
<td>Attempting to reconcile disagreements</td>
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<tr>
<td>Asking for factual clarification</td>
<td>Helping to keep channels open</td>
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<tr>
<td>Offering facts</td>
<td>Being friendly and responsive</td>
</tr>
<tr>
<td>Interpreting ideas or suggestions</td>
<td>Offering alternatives in conflicts</td>
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<tr>
<td>Pulling together related ideas</td>
<td>Expressing standards for the team</td>
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The Spring 2003 EPICS Challenge exemplified the type of design-and-build projects that the program has initiated over the past several semesters. The Colorado Space Grant Consortium (CSGC) in conjunction with the Jet Propulsion Laboratory (JPL) and Ames Research Center (Ames) challenged our first-year students to develop modules for measuring various atmospheric conditions during a high-altitude balloon flight. The mission of the project was to develop, prototype, and test new technologies and innovative concepts. The theme of the CSM project was “atmospheric measurements.” Our teams designed, developed and constructed satellites to demonstrate instrumentation and data acquisition functions for use at high altitude. Scientists and engineers from JPL and Ames participated with students providing guidance and interactions as well as attending team reviews and the launch.

The flight reached altitudes that created some tough and challenging design issues for the teams. Temperatures dropped to -80°C, and pressures reached near vacuum conditions. During the initial descent following the balloon burst, the craft reached speeds of Mach 1. Condensation became severe as the units reached lower altitudes.
The construction phase of the project focused heavily on the construction of satellites beginning with a solder and foam core training clinic. Students (Figure 2) practiced soldering resistors to PC boards and constructing a simple light-switch system in preparation for building their instrumentation packages. Teams explored, developed and tested packages that range from manual system to data acquisition systems to software enhanced control systems. Many teams pushed the boundaries of their technical skills as they attempted to use a “BrainStem” system marketed by Acroname Systems of Boulder.

Once teams completed harnesses for their instrument packages, they began construction of the satellite shells (Figure 3). Most teams chose to use foam core for the majority of their shell exterior. Teams practiced cutting and grooving the foam prior to working on their shell. Satellite shapes often varied from the convention cube or pyramid shape creating some challenging opportunities for the teams.

Teams brought together all the components to showcase their products. They worked together to 1) complete design reports, 2) assemble graphics portfolios, 3) construct prototypes and 4) prepare market presentations. By the end of the project, teams performed with little guidance from the mentors.

**PROJECT REWARDS**

At the Spring 2003 EPICS Celebration and Exhibition, several teams were awarded recognition for their designs. Design categories awarded to the participants covered the full range of design performance criteria from technical excellence to aesthetics.

- Most Educational Satellite (K-12 Award)
- Best Presentation of a Satellite (Displays for Jefferson Symphony)
- Best Application of Sensor Technology (Represent CSM at the Sensor Exhibition)
- Most Robust Design (Represent CSM at the NASA RASC-AL Conference)
- Best Overall Design of a Satellite (Represent CSM at the Launch)

Student from the Conifer Middle School evaluated the satellites for educational value to K-12 students. They struggled to pick the best two teams because of the variety of unique satellites. Ultimately, they selected Team From Scratch’s ComboSat and Team Broccoli’s LandSat based on their demonstration of satellite concepts.

The Jefferson Symphony performed a concert in May 2003 around the theme “Travel to Mars”. Organizers for the event selected Team Menikini’s GPSSat and Team Heads Up’s CrashSat. Each team received tickets to the concert for the Best Presentation of a Satellite.

Team Cadillac in the Sky created a satellite that demonstrated Best Application of Sensors Technology. Advanstar Communications Inc., in conjunction with the Design (EPICS) Division, sponsored a trip for two members of the team to participate in Sensors Expo Emerging Technologies Pavilion in Chicago. Stephen Esquibel and Brent Wildenstein exhibited their RoverSat (Figure 4) and delivered a brief presentation about the design of their rover and satellite to conference attendees and vendors. They appreciated the opportunity to experience first hand the conference but specifically as exhibitors on the pavilion floor.

**THE LAUNCH AND FLIGHT**

The rising sun on August 2, 2003 began the final phase of the DemoSat Project. Teams from 13 universities throughout Colorado converged on Deer Trail, Colorado to launch their satellites on two high altitude balloons. Jason Wagner (Figure 5) representing Team Dasjra was one of the first to tie the team’s LandSat to the tether on Balloon 70. His satellite was designed to record pictures during the descent back to the surface.
This satellite explored using an historic pressure devise to initiate the electronics for taking pictures during the decent. A Baroswitch or pressure sensor initiated the satellite's functional system at approximately 10,000 ft. The switch triggered a circuit and a pair of solenoids to take pictures every five seconds during the descent.

Team Broccoli chose to focus on a LandSat to land, orient upright, and take a picture of the surrounding area. The day of the launch didn’t go quite as smoothly as the team had planned. The launch sequence required the team to initiate the timer switch prior to the lift-off. A glitch in the program, however, caused a flurry of activity to modify the program. The local high school secretary kindly provided access to the high school at 5:30am giving them access to a computer. Team Broccoli (Figure 6) with the help of several residents finally turned on their Brainstem, and tied to the tether of Balloon 71 minutes prior to the launch.

A caravan of cars began the chase traversing the back roads around Limon as the balloon rose into the upper atmosphere, exploded and descended back to the Earth’s surface. Satellites from Balloon 70 landed safely in a field approximately 2 mi from any highway in a location where most of the land was used for cattle ranching and dry land farming. Arriving at the site, Jason confirmed that the structure of Team Dasjra’s LandSat (Figure 7) was intact. Although expecting to hear a solenoid depressing the camera button, Jason did not detect activity within the satellite. After opening the upper pyramid, he observed that the Baroswitch performed its designed function. Sometime during the flight, however, the batteries that powered the system were dislodged from the battery pack leaving the camera inoperative.

Although pictures were not taken, the project was a success. The structure withstood the harsh conditions of the flight. The Baroswitch (Figure 8) operated well under the conditions, a major success since this was one of the objectives of the experiment. The issue of the batteries illustrated that despite the planning and design going into a launch, design issues can sometimes be overlooked that lead to a loss of data. The project demonstrated that we as engineers must learn, often through experimentation, that attention to all details, even the smallest details, influence the success of a project.

Team Broccoli on the other hand found that their satellite successfully landed and oriented upright, but not in the manner that they had planned. Their satellite landed about 0.25 mi from the road and was much easier to find. The opening was more violent than expected (Figure 9). The strings attached to each of the four walls of the satellite were wrapped around a pin that was triggered to release when the timer switch activated after landing. The strings were attached to the foam core walls using bolts. One bolt pulled through the wall either during the flight or upon impact and prematurely opened the satellite.
Over all, Team Broccoli’s LandSat was a success and a great learning experience. Their satellite accomplished its goal to land, orient upright, and take a picture. The sides deployed and brought the satellite to its upright position triggering the camera. The resistor-heating unit was working when the team got to the landing sight (Figure 10), and the foam core and aluminum tape they used to make the satellite were still intact. Once the satellite opened, it took a picture of the surrounding area. The picture was dark and blurry, either due to the quality of the camera or to film exposure at the extreme conditions of the flight.

FIGURE 9
Team Broccoli’s LandSat in an Open Position at the Recovery Site.

FIGURE 10
A Successful Landing and End to An Educational Opportunity

CONCLUSION
The CSGC DemoSat Project ended with successful conclusions and satisfied team members. Team Dasjra’s LandSat illustrated the operability of a classical pressure sensor. Team Broccoli’s LandSat demonstrated the overall structural design of their satellite and the function of the electronics. The student returned from the landing sites with a sense of accomplishment having successfully designed, built, and launched a satellite.

NASA’s sponsored DemoSat project created the authentic environment for first-year Design (EPICS) students to practice their engineering design skills. Managed by the Colorado Space Grant Consortium, the project served as a role model for industrial based design projects. Students worked for an authentic client with actual needs. They identified options and developed specification to design and construct a weather satellite. They observed first hand the importance of detail and accuracy to complete all the activities necessary to build a quality product. The project reinforced the Design (EPICS) focus on an engineering design methodology.

The project encourages teamwork and cooperation just to complete the project. The scope of work exceeds the ability of a single student working in a semester time frame under normal class loads. Project specification, especially the budget constraints, reinforces both creativity and confidence among team members. Dividing the project into subsystems teaches the students not only about a systems engineering approach to design but also supports the value of roles that team members assume. Students learn to trust each other by building the confidence that they will respond to the deadlines. The rewards for an outstanding effort complement the project.

We close the Spring 2003 EPICS Challenge with a sense of pride and a warm thank you to all who participated, supported and contributed to the students’ learning. We acknowledged the CSGC for the project, the support and the opportunity to publish this paper. We congratulated Team Dasjra and Team Broccoli for their stellar performance as representatives of the first-year students at CSM.

REFERENCE


[5] Jones, J.E., Productive and Counter Productive Role Behaviors of Team Members, Organizational Universe Systems, Valley Center, California, 1999