THE WPI / GODDARD SPACE FLIGHT CENTER PROJECTS PROGRAM

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Abstract - The WPI/GSFC (Goddard Space Flight Center) Projects Program is an off-campus, multi-disciplinary opportunity for students to complete their capstone design project requirement during 10 weeks of on-site project work. Students accepted into this program are required to spend one term in a project preparation course where they carry out background research, interact with their project mentor(s) at the space center, and write a detailed project proposal. At the completion of the preparation course and several weeks before the start of the following academic year, the students relocate to the Washington area and work full time for ten weeks on their projects at the Goddard Space Flight Center. This project center is at the forefront of the WPI emphasis on "real world" project experience as a cornerstone of its undergraduate educational plan. Among other benefits, this off-campus program clearly demonstrates that significant contributions can be expected from WPI student teams working on complex engineering and science projects.

Index Terms - Undergraduate Program, Projects

INTRODUCTION

WPI was founded in 1865 to create and convey the latest science and engineering knowledge in ways that would be most useful to the society from which its students came. Since that time, the disciplines of human inquiry have expanded in extraordinary ways, as have WPI's constituencies. The WPI curriculum, accordingly, has been reshaped numerous times, but it has remained true to its original mission of fusing academic inquiry with social needs, of blending abstraction with immediacy and of linking new knowledge to applications.

In 1970, the WPI faculty introduced a new way to merge theory and practice. Called the WPI Plan, it did away with the traditional technological program of the time. In its place was created a project-based curriculum that gave students the flexibility to design their own program to suit their interests, and the tools for gaining the skills and abilities they needed to excel as technological professionals.

THE GLOBAL PROJECTS PROGRAM

The vehicles for merging theory and practice are independent projects, the cornerstones of which are two three-course-equivalent project experiences, one in the third year of study and one in the fourth, or final year of study.

The third year cornerstone project is designed for students to develop an understanding of the linkage between technology and society. Since the mid-1970's it has been possible for students to complete this project during one term of intensive study and work at a "project center". As a result of a significant expansion in the 1990's of the centers available for third year project activities, more than half of all WPI students complete their third year project off campus through what is now known as the WPI Global Program. For these students, opportunities exist at centers in locations as globally dispersed as Washington DC, Bangkok Thailand, Melbourne Australia, Copenhagen Denmark, London England, San Juan Puerto Rico, and Boston Massachusetts.

The fourth year cornerstone project is known as the Major Qualifying Project, or MQP. This project must be in the student's major area of study and is designed to demonstrate the application of the skills, methods, and knowledge of the student's discipline to solving a problem representative of the type to be encountered at a professional level. An MQP encompasses a broad range of technical project activities and satisfies the *capstone design experience* required by ABET of all accredited engineering colleges.

Until the mid-1990's, the vast majority of MQPs were completed on-campus - - in stark contrast to the typical third year project experience where the majority of students completed this project off-campus, thus gaining an invaluable global perspective to problem solving. Because of the perceived benefit of off-campus project opportunities, in the last 5 to 6 years WPI has developed specific opportunities for students to complete their fourth year project at one of several locations in the US and abroad.

THE GODDARD CONNECTION

As a result of an interest by the authors, we attempted to identify a corporate entity where we believed a long term relationship could be established for the development of an "MQP Center" for students with a wide range of backgrounds. Foremost among those sites identified was the Goddard Space Flight Center (GSFC) where, not to surprisingly, WPI had an important supporter in Dr. Richard Freeman, the Chief Engineer for the Advanced Engineering Technology Directorate.

After initial contact in mid-1996 and several planning trips later that fall, an agreement between Goddard and WPI was signed wherein Goddard would host WPI engineering students for one academic term a year of on-site project work. This agreement was of interest to Goddard

since the Program offered an opportunity to join WPI in providing a real-world educational experience for future engineers, scientists, and managers. At the same time, the program provided Goddard mentors with fresh and creative approaches to problem solving by university students under the guidance of WPI faculty.

The choice of GSFC as WPI's first residential interdisciplinary MQP center is significant in that it fits into the GSFC Education Strategic Plan through the elements of the Goddard plan to;

- Expand the impact of programs by developing partnerships with external constituencies.
- Involve educational institutions, at all levels, in cooperative efforts to stimulate interest in science and engineering and to foster development of the future work force.
- Forge mutually beneficial partnerships with the national and international science communities, other governmental organizations, the private sector, academic institutions and the local community.

From the WPI perspective, specific objectives incorporated within the development of the Goddard Space Flight Center Projects program include;

- a single term off-campus fourth year project opportunity,
- providing projects to multiple engineering and scientific disciplines, and
- providing an opportunity for WPI students to work on an intensive and focused team project in a professional technical environment.

PROGRAM CALENDAR

The time-line presented and described below outlines the year-long effort required to implement and manage this program.

November-December
With the help of our Goddard on-site coordinator[3], projects are solicited from the GSFC professional staff. Projects typically can be elicited from the Goddard Staff for students in the following areas.

- Chemical Engineering (materials, coatings, processes, applied research)
- Computer Science (analysis, programming tool development, systems)
- Electrical and Computer Engineering (analysis, design, program and systems development in support of instrumentation, sensors)

- Mechanical/Aerospace Engineering (modeling, analysis, design, orbital and launch systems, thermodynamics)
- Physics (low temperature physics, sensors, instrumentation, design, materials, analysis)

Concurrent with project solicitation, students apply to the program and are interviewed. Just before the December break, students are notified of their acceptance to the program. In some cases, students are told that they are "conditionally" accepted - and are fully accepted once a project has been identified. The reason for doing this is simply that at times there is a miss-match between the number and types of students applying, and the types of projects proposed by the Goddard mentors.

January - February
Descriptions of the selected projects are provided to the students who then rank them according to their personal interests. The students are also asked to identify which team members they do and do not want to work with. While only minimal effort is made to assign students to teams with "friends", every attempt is made to create teams that at least do not have students who dislike each other! Other tasks during this time include,

- notifying Goddard mentors which projects were selected
- finalizing an activity report to NASA for the previous year's project work
- writing a new proposal for the project year that is being organized
- contacting the housing provider in College Park to reserve rooms
- scheduling and making arrangements for a project preparation class.

March - May
The students are required to participate in a project preparation class (*see below*).

August - October
On-site project phase (*see below*).

PROJECT PREPARATION CLASS

The primary objectives of this class are for the students to i) establish a relationship with their Goddard mentor(s) and their WPI advisor(s), ii) learn as much as they can about the project to which they ae assigned, iii) identify the key technologies and problem solving methods involved, and iv) write a detailed project proposal. Additional topics covered in this course also include the following (not a complete list).

- housing, travel and safety issues

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[3] M r. Stephen Brodeur, a Division Leader in the Mechanical Systems Branch, and a 1969 WPI graduate.

- expenses, costs, what to expect
- behavior, both at work and while not at work
- disciplinary procedures
- emergency procedures, contact information, how to get help
- local travel, entertainment, events, opportunities
- organizational issues (deadlines, reports, meetings, keeping advisors informed, etc)
- writing an excellent report - how to, where to get help, expectations, deadlines
- methods and training for making oral reports

The highlight of the preparation project is a one-day trip to Goddard. Arrangements are made so that the WPI student/faculty group arrives at Goddard early in the morning (flying from Providence, RI to Baltimore, MD). Morning activities include introductory meetings where Goddard administrators welcome the students, describe the Goddard Mission and culture, escort the students on a tour of the facilities and join us for lunch on-site.

Immediately after lunch, the students have about two hours for team meetings with their mentors, in their mentor's laboratory or office. These meetings are the focal point of the trip - where the students have time for serious discussions with their mentors to assess progress on their proposals, to assess their understanding of the project, and for the students to become comfortable with the setting and people they will be working with at the end of summer break. Later in the afternoon, the group meets for the flight back to WPI.

ON-SITE PROJECT WORK

Students are expected to be in their apartments the Saturday prior to the start of on-site work, and an advisor (usually FJL) joins them for the first two weeks. Although most off-campus projects last only the duration of a single term (7-weeks), early difficulties with completing a technology project in seven weeks has resulted in the program being extended to 9-10 weeks, depending on the particular academic calendar that year[4].

Concurrent with their project design, analysis and/or research/development work, each team is required to write a detailed project report and to present their results during a formal, end of term public presentation. As a result, not only are the students working during the day on their projects, but they are also spending significant time in the evenings and weekends writing reports, performing analysis, and preparing for oral presentations and reviews.

During the on-site work phase, all WPI project advisors spend one or more weeks at Goddard working with their team(s), and by mutual agreement advising all other project teams as well. Thus, for example, it is not unusual

for a Chemical Engineering faculty advisor to spend several hours with a Computer Science team, reviewing their progress and making suggestions. Later in the day, each advisor emails back to WPI the results of the team discussions so that the WPI faculty advisors of record have an enhanced sense of how the student teams are progressing.

SAMPLE PROJECT DESCRIPTIONS

The breath of areas and activities spanned by the projects that have been completed in the past five years at Goddard are a testament to the viability of this project center for a broad range of student projects. Several representative projects are described below.

Design of Wireless Biotelemetry Unit (ECE)
The purpose of this contract development project was to design and prototype a small wireless biotelemetry unit to transmit embedded electrode data gathered from a laboratory rat as part of drug dependency studies for a University. Although not strictly a "space flight" project, Goddard was interested in this contract work since it had applications to animal studies on Space Station. The primary problem encountered by the students was that there were no off-the-shelf circuits or systems available that would meet the data rates needed. After considering numerous digital, analog and hybrid solutions, the students developed a complete working system, using analog multiplexing, custom FPGA switching for signal multiplexing and framing, and a phase locked loop microwave receiver that was completely mathematically modeled, and worked exactly as predicted - in spite of more than skeptical advisors!

Generation of Detailed International Space Station Scenarios (ME/AE)
Detailed external payload viewing scenarios of the International Space Station (ISS) were needed by scientists to determine optimum mounting locations for scientific payloads. This project entailed the generation of the software and visualization tools necessary to assess the best location for payloads, the lines of site for each location as a function of orbital location and the obscurations encountered at each mounting location. The final visualization tools not only met the expectations and goals set for by the project mentor, but also clearly illustrated to the Goddard mentors the information and procedures needed to generate such information.

Graphical Analysis for Clustered Systems (CS)
The purpose of this project was to create an analysis and visualization tool that would aid software developers in writing efficient parallel code for clustered systems and for identifying problems with a clustered system. This visualization tool, known as Graphical Analysis of Clustered Systems (GACS), was designed to analyze program operation and inter-program communications on a clustered

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[4] The 2002 AY program runs from Saturday, August 10 through Friday, October 11 for a total of 9 weeks.

system (e.g. a Beowulf cluster) and afterwards present the user with a graphical representation of the performance of each node of the cluster based on tracked information. In spite of difficulties with a new Beowulf system that the students used for program development, the tool was able to immediately and unequivocally demonstrate that there were problems with back plane communications between processes running on the cluster.

VHDL Implementation of Automatic Cloud Cover Assessment (ECE)

The goal of this project was to implement an image processing algorithm using Reconfigurable Computing technology. Images from the Landsat 7 satellite are currently processed using an Automatic Cloud Cover Assessment (ACCA) algorithm in C++. In order to reduce processing time, the algorithm is being implemented in VHDL on an Annapolis StarFire FPGA board. As the fourth in a series of projects in this area, the students were tasked with a particularly difficult phase of the project. Their efforts resulted in a prototype system that exhibited a significant improvement (5-10x faster) over the C++ based code it was designed to replace.

Design and Testing of an Advanced Adiabatic Demagnetization Refrigerator (PH/ME)

The Cryogenics Group at Goddard Space Flight Center (GSFC) is developing an Adiabatic Demagnetization Refrigerator (ADR) to provide continuous cooling at 50 millikelvin. The components of the ADR the student team studied were heat switches, paramagnetic salts, super-conducting magnets, and magnetic shielding. The students researched materials and designs for these components and then proposed an advanced 4-stage ADR system after testing the thermal efficiency of the current 3-stage ADR system. Several of the mentors remarked on the novelty of the final design and the quality of the thermal, structural and dynamic analysis that accompanied and supported the design.

Optical Encoder Technology Development (ECE)

The purpose of this project was to design and implement a prototype of an absolute optical encoder that uses novel imaging methods to produce outputs with extraordinary accuracy. The design involved the development of an high speed embedded system to control a custom CCD camera interface, receive pixel intensity data through a custom address decoder, process encoder images, and output absolute position to the user or an external device. Of particular interest to the Goddard mentor was the desire to increase the sample processing speed of his current prototype from about 20 position updates a second to 200 updates/second. The reason for this was that the patented system was of interest to a commercial venture, but only if the update rate could be improved. Using a combination of high speed analog electronics, high speed/high capability analog acquisition components, custom PCB designs, and a

digital-signal-processing board with custom programming, the students were able to demonstrate a completely functional system that could generate more than 3000 position updates/second with no loss of encoding accuracy.

ISSUES AND CHALLENGES

Five years of experience have led us to identify factors that have a significant impact on the quality of the projects and/or the value of the experience to the students. Several of these factors are noted here.

1. A mentor who is "assigned" to the students because it is perceived to be good corporate policy will often, regrettably, not respond to student needs in a timely manner - a critical problem for a short term project. Consequently, it is imperative that the on-site mentor be a volunteer and want to mentor the students. In the same sense, it is crucial that the support needs of a student team be met as quickly as possible. This can happen either through the mentor providing the support directly, or more likely, by empowering the students to obtain the support they need by introducing them to appropriate support staff or, for example, providing them with ordering account information and guidelines.

2. In nearly every case where a Goddard mentor has proposed a project, that mentor has stayed with the program for more than one project year because of the quality of the work, the commitment of the students, and the ability of the students to solve significant problems and, thus, aid the mentor in their own work. It has been our experience that when a mentor drops out of the program, it is because s/he does not have a project for a student team that year, not because of a marginal experience. This long term commitment by Goddard mentors means that new student teams often have mentors who are familiar with what the students can accomplish in a short period of time, and are also familiar with the student needs - often having had to meet similar needs with a previous project group.

3. At Goddard, every project is a "real" project with real expectations. There are no "make work" or less unimportant projects. Every project team is fully integrated into the laboratory where the mentor(s) work. As a result, the students are fully aware of the importance of their work - which leads naturally to better efforts on the part of the students. There is also a heightened sense of pride in the work - by both the students and their mentors.

4. The first two weeks of the on-site work are the most crucial. The on-site faculty advisor(s) must insure that the student teams are off to a good start, are obtaining the resources they need, and are clear about the project

objectives, particularly if they have been changed during the summer as a result of project realignments. In the middle phase of the on-site project work, it has been our experience that a faculty advisor need only be present for perhaps 2-3 days a week to check progress, discuss issues and help with any project problems. The final two weeks are, again, crucial to the quality of the final reports and oral presentations. For example, during this time the resident advisor (FJL) will review and rehearse each team's oral presentation until the students understand the expected quality, and are comfortable with both delivering a lengthy technical presentation and answering unanticipated questions from the audience. The resident advisor will also review and edit all project reports and executive summaries - a substantial commitment of time and effort.

5. The solutions proposed and implemented by the students are often well beyond what mentors expect for fourth year engineering students, and typically not the solution expected. Many times the Goddard mentors have remarked that the solutions are unique, creative and innovative well beyond their expectations.

6. By the middle of the on-site project experience, it is not unusual for student teams to work nearly nonstop. The perception (and to some extent, the truth!) is that there is always something more that can be done that would "add" to a project. The most challenging problem for the WPI advisors at this point is to limit the student work to a manageable level.

SUMMARY AND CONCLUSIONS

WPI's experiential approach to learning and the seven-week academic terms have provided a basis for an innovative project-based global studies program. The WPI Global Program and specifically the Goddard Project Center is at the forefront of the WPI emphasis on "real world" project experience as a cornerstone of its undergraduate educational plan. Among other benefits, this off-campus program clearly demonstrates that significant contributions can be expected from WPI student teams working on complex engineering and science projects. To date, more than 100 students have participated in this program.

Graduates of the program say the required project work is excellent preparation for managing team efforts and for communicating - orally and in writing - in a professional manner. They note that the projects foster qualities vital to their career success and their enjoyment of life, including creativity, leadership, teamwork, goal setting and critical thinking ability. As one component in the WPI Global program, the WPI/GSFC Projects Program has proven to be an extraordinary opportunity for students to complete their fourth-year capstone experience.