

Engineering in Context:  
A Multidisciplinary Team Capstone Design Experience  
Incorporating Real World Constraints

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We [engineers] also do not readily focus on the big picture. This is perhaps why we haven't always seen ourselves as agents of change...We need to help them [engineers] contemplate their work in the larger context because what they do often changes the 'big picture' dramatically over time. That 'big picture' encompasses economic, political, social, and ethical components.

It is important, but not enough, that engineers are taught excellence in design to achieve safety, reliability, cost and maintenance objectives. It is important, but not enough, to teach them to create, operate and sustain complex systems. It is important, but not enough, for them to understand and participate in the process of research. It is important, but not enough, for them to develop the intellectual skills for life-long learning....  
Engineering is not just about doing things right, but also about doing the right things.<sup>1</sup>

NSF Acting Deputy Director Joseph Bordogna at the MIT Club,  
“Next Generation Engineering: Critical Trajectories, Holistic Approaches”  
September 12, 1997  
(emphasis added)

### Introduction: Focusing on the Big Picture

In the Spring 2003 semester, the School of Engineering and Applied Science (SEAS) at the University of Virginia introduced a new three-course sequence to provide engineering students with a multidisciplinary team capstone design experience. The sequence begins in the spring of the junior year, continues through the senior year, and is designed to help students “contemplate their work in the larger context” that includes “economic, political, social, and ethical components.” This initiative, called “Engineering in Context” (EIC), addresses the concern that engineering graduates are frequently ill equipped for the interdisciplinary, collaborative, and cost-driven environment of the professional engineer.

The EIC program also responds to the ABET Criterion 4 requirement, which states that “Students must be prepared for engineering practice through the curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating engineering standards and realistic constraints that include most of the following considerations: economic; environmental; sustainability; manufacturability; ethical; health and safety; social; and political.” These “considerations” are the contextual aspects that form the philosophical umbrella over the University of Virginia’s Engineering in Context initiative.

This paper describes the evolution of the new EIC course sequence from concept through development, implementation, and assessment. Further, the paper describes the integration of the engineering in context philosophy, which incorporates “real world” aspects, into the engineering curriculum.

Four features of the EIC initiative are particularly worth noting at the outset. Specifically, the program is designed to:

- 1.) Cross engineering departmental boundaries. It is administered on a school-wide basis, and the students not only work on multidisciplinary projects, but also on multidisciplinary teams (there may be no more than two engineers from any one discipline on a particular team).
- 2.) Be scaled up so that all students who want a truly multidisciplinary experience can have one, regardless of their major.
- 3.) Eventually encompass the entire curriculum so that the context of engineering practice is made real to students at every level from the freshman year through the culminating sequence described in this paper. (Pilot programs are currently under way at the freshman level as well.)
- 4.) Fully explore the problem definition process. One of the primary advantages of considering a problem in context is that one gets a clearer sense of what the problem really is and sees the truth of Joseph Bordogna’s assertion that “Engineering is not just about doing things right, but also about doing the right things.”

The three-course sequence on which this paper focuses begins with a one-credit course for second semester engineering juniors. Titled ENGR 302: Engineering in Context, this course interactively teaches the contextual and problem solving aspects of contemporary engineering. As part of ENGR 302, students work individually or in teams of two or three to propose solutions to problems that have interesting contextual aspects in addition to posing challenging technical problems. The best proposals are funded for continuation through the fall and spring semester of the student’s senior year. The successful proposers become team leaders who assemble multidisciplinary teams whose work is structured through the second and third courses in the sequence, which are titled Multidisciplinary Team Design and Development Project I and II (ENGR 401 and 402, respectively). ENGR 401 and 402 build on the contextual learning from the junior level course and provide a real world design experience mentored by faculty and, in some cases, industry clients.

## Background and Motivation

The program we describe in this paper responds to the changes in the profession of engineering and the context of engineering practice that drove ABET 2000 and that are widely recognized both within and outside of academia. Traditionally, engineers have been recognized as professionals and educated in the employment of sophisticated analytical tools based on physical principles that are important to the development of new products and processes; however, many engineering curricula have lacked sensitivity to contemporary issues as commonly taught in the humanities and social sciences. In other words, they lack a well-developed awareness of the ways in which the context of engineering practice shapes the technical aspects of engineering

and engineering shapes the larger organizational and cultural contexts in which technology is developed and implemented.

All aspects of our society (industry, government, and education) are infusing technology into their work processes to gain competitive advantage and improved productivity. International competitive pressures and the demand for higher quality, lower cost technology have increased demand for well-educated engineers. Also, the development, implementation, maintenance, and management of technology require sophisticated leadership from the engineering profession.

However, as many studies and leaders have concluded, our graduating engineers are not prepared to address the new constraints of collateral impact of technology and the risks posed by unintended consequences. Therefore, engineering educators must now plan for the next step in the evolution of engineering education to prepare students for the leadership challenge of developing technology in an organizational and cultural context. Contemporary engineering leaders increasingly depend on understanding the processes and consequences of technological and social change. With greater than 50% of all engineers now occupying managerial positions,<sup>2</sup> this need for understanding and managing the cultural aspects of engineering is even more critical.

A 1989 MIT Commission on Industrial Productivity singled out curricular reform in higher education as one key to arresting the nation's declining industrial competitiveness, calling for students characterized by:<sup>3</sup>

- Interest and knowledge of real problems and their societal, political and economic context
- An ability to function effectively as members of a team to create new products, processes and systems
- An ability to operate successfully beyond the confines of a single discipline
- An integration of deep understanding of science and technology with practical knowledge, a hands-on orientation, and experimental skills and insight

Our own understanding of the problem led to the formulation of the following objectives for the EIC program:

- to prepare students to make a more immediate contribution to an engineering project by exposing them to the organizational and team-based culture, cost/performance issues, regulatory environment, and systems-based approaches that characterize industry projects
- to prepare students to assume leadership positions by orienting them to the social, economic, and ethical environments in which technology development occurs
- to stimulate resourcefulness and creativity by providing design/build experiences that result in the production of a product.

The overarching philosophy behind the development of the EIC program has been to take advantage of the synergy that exists among industry objectives, ABET requirements, and the

distinctive strengths and mission of our institution while also being realistic about constraints and the need for the faculty buy-in that is crucial for full-scale implementation of the program.

Our vision for the program began to take concrete form in the spring of 2002, when Lockheed-Martin expressed interest in funding a pilot engineering course that would provide senior level students with a real world, multidisciplinary, team-based design experience. Under the leadership of Dean Paxton Marshall a small ad-hoc team of SEAS faculty was called to discuss approaches for meeting Lockheed-Martin's expressed interests. The brainstorming process that followed quickly determined that there was synergy between Lockheed-Martin's interests, the requirements of ABET Criterion 4, and the existing senior thesis requirement of the School of Engineering and Applied Science. Perhaps more significantly, the school's STS department already had the expertise required to help engineering students understand technology in organizational and cultural context. What was still needed—and what the EIC program sought to provide—were (a) a *multidisciplinary* team design experience and (b) greater opportunity to shape and work on projects to which cultural and organizational considerations were central rather than peripheral or absent.

### Strategies and Guiding Principles of the Curriculum Development Process

We employed four specific strategies and guiding principles, which are discussed in more detail below: (1) build on existing strengths, (2) embrace truly interdisciplinary course design and team teaching, (3) coordinate closely with our industry sponsor, and (4) reach out beyond the core group of pilot program faculty to achieve the faculty buy-in necessary for full-scale implementation of the program.

1.) **Build on Existing Strengths: Department of STS and Existing Thesis Requirement.** The two most important strengths we had to work with were our school's department of Science, Technology, and Society and an existing senior thesis requirement. For over 70 years, the School of Engineering and Applied Science at the University of Virginia has incorporated the humanities and social sciences (HSS) into the engineering curriculum through its Department of Science, Technology, and Society (STS—formerly known as Technology, Culture, and Communication, or TCC). STS is an interdisciplinary group of humanities and social sciences faculty located within SEAS. The students take roughly 40% of their humanities and social science requirements (4 courses) in interdisciplinary HSS courses designed for engineering students. (The remaining 60% of the HSS hours are selected from those offered by departments in the College of Arts and Sciences and designed for a general student population.) The STS course work provides an integrative framework and intellectual foundation that help students develop an in-depth understanding of the contextual aspects of engineering practice.

STS also manages the undergraduate thesis project that has been a graduation requirement of SEAS for nearly 100 years and a major part of the engineering curriculum since the early 1930's. Students may draw on the work they do for the Engineering in Context program as the basis for an undergraduate thesis. An undergraduate thesis project may involve either engineering research or design and should give the student who undertakes it the opportunity to synthesize the various elements of his or her undergraduate education. Each thesis is jointly advised by a faculty member from STS and a faculty member, usually from the student's major department,

who is an expert in the technical field of the thesis. The students define and complete the undergraduate thesis within the framework of two fourth-year courses: STS 401: Western Technology and Culture and STS 402: The Engineer, Ethics, and Society. The thesis project requires them to consider and integrate all of the Criterion 4 constraints and considerations.

Through many years of advising theses, the STS faculty members have come to realize that the kind of project a student undertakes makes an enormous difference in how well that student can use the project as a case study in cultural and ethical issues. For example, if the project is strictly laboratory research and not connected to any particular social need or ethical and organizational context, the case study aspects will seem forced, artificial, and shallow. On the other hand, if the student's project and problem are clearly rooted in concrete social needs and realistic ethical and organizational contexts, the project serves as an excellent case study, and the student gains new depth of understanding of the problem the project seeks to solve. Consequently, the STS faculty welcomed the well contextualized thesis projects that the EIC program promised to create.

From the beginning, the EIC program worked closely with STS in the development and teaching of the new courses and the integration of the new courses with the existing courses in which the thesis is managed. Although increasing numbers of students have drawn on group projects for the substance of their thesis, most theses have been conceived as individual projects within a single discipline. The EIC initiative is designed to provide a parallel path alternative for students who seek a multidisciplinary team design experience. Each student on the team must still produce an individual thesis product. That thesis product would be his/her individual aspect or responsibility of the overall team project.

For example, one team is developing a reconnaissance robot that could be used by SWAT teams to sense nuclear, biological or chemical threats. Each team member has a very distinct and differentiated aspect or responsibility that will be described in an individually written senior thesis. One member, a mechanical engineer, is responsible for the drive train design and development. Another mechanical engineer is responsible for the suspension and bumper design and development. An electrical engineer is responsible for the wireless information/control design and development, and the final team member, a computer science major, is responsible for the software design and development.

As a result of these arrangements, the EIC program is an excellent source for undergraduate theses that not only produce tangible results but also provide outstanding educational experiences. In turn, the resources and support of STS provide an essential foundation for the EIC program. In addition, the EIC program supports the school's strategic plan goal to "Create a dynamic curriculum combining depth through disciplinary studies and breadth through interdisciplinary experiences that ensures that all our students have the knowledge and leadership skills to be successful in their careers and productive citizens." The strategic plan further asserts, "Engineers do not act in isolation. It is imperative that we expose our students to the real-world challenges and constraints facing engineers." In summary, then, the EIC initiative allowed us to build on existing strengths within our school and to achieve one of the school's most important strategic objectives.

2.) Embrace truly interdisciplinary course design and team teaching. The first three authors of this paper (Neeley, Elzey, and Bauer) volunteered to create the new course sequence. These individuals brought a variety of expertise and experience to the project: Neeley (STS/historical, cultural, and ethical contexts of technology), Elzey (Materials Science and Engineering/teaching engineering design), and Bauer (extensive industrial experience/product innovation and industrial management). At the beginning of the planning process, we contemplated a traditional team-teaching model in which the various faculty involved teach in sequence (i.e., dividing the course into thirds and teaching one-third of the classes each). We soon realized, however, that our goals could only be achieved by true team teaching in which an integrated approach comprising all of our perspectives was used both to the design the course as a whole and to plan and teach all of the individual class sessions.

Such an arrangement requires that the instructors possess flexible and cooperative spirits. These traits are necessary to ensure the successful integration of the quantitative aspects of engineering with the more qualitative aspects of organization and culture. ENGR 401/402 required instructors that combine the attributes of a program manager with those of a technical advisor. As we discuss later, finding people with these traits and attributes is an ongoing challenge. We also believe, however, that it is worth the effort and yields significant intellectual benefits. For example, the EIC philosophy, which we discuss later in this paper, incorporates the multiple perspectives of the faculty who were involved in the designing the course.

3.) Coordinate closely with our industry sponsor. The support we have had from Lockheed Martin not only provided important financial support but also helped us refine and confirm our understanding of what the EIC program needed to achieve, the gap it needed to fill between what academic institutions are currently achieving and what industry needs. Thus, having industry involvement was deemed important to providing the students with a more “real world” experience. To ensure close coordination with Lockheed-Martin, Gary Hatter, Virginia Engineering Foundation, Director of Corporate and Foundation Relations, joined the team and quickly established communication with the Lockheed-Martin team of Dave Kohn, Manager, Surveillance and Surface Ship Engineering Lab, Manassas, VA; Jim McCann, Southeast Campus Relations Manager, Orlando, FL; Steve Osborne, Naval Electronics and Surveillance Systems, Undersea Systems, Manassas, VA; Stephen Race, Chief Information Officer, Federal Systems, Manassas, VA; and Vicki Staton, Program Director, Management and Data Systems, Reston, VA.

In the fall of 2003, early in the course planning process, to build excitement and interest with faculty and engineering students, Lockheed-Martin was invited to participate in a kick-off meeting where the EIC objectives and the planned course content were presented. Then, in the spring semester of 2003, ENGR 302 was launched, and Lockheed-Martin was invited to a special class session where they presented a variety of technically related problems that they were contractually obligated to solve for select customers.

For example, Lockheed-Martin was under contract to review and make recommendations for improving the United States railroad system, one part of which was to improve railroad worker safety. A representative from Lockheed-Martin presented the safety problem to the class, described how workers are often struck by passing trains, and articulated the general goal of

solving this problem by employing contemporary technology and system integration approaches. The students were encouraged to ask questions of Lockheed-Martin at the meeting and later, if necessary, by phone and email.

Two of the seven winning proposals were problems that Lockheed-Martin presented. The teams that were formed to address these two problems then established contact with Lockheed-Martin engineers and program managers and through-out the two semesters remained in close contact on technical, budget, and schedule issues, much as a project team might experience in the real world of professional engineering.

Finally, Lockheed-Martin will participate in the semester ending product demonstration presentations scheduled for this May 2004, which will be the first class to complete the EIC sequence.

4.) Reach out beyond the core group of pilot program faculty. As anyone who has studied or participated in curricular innovation knows, many good ideas have no long-term positive impact because the core group of innovators who originate and pilot the program never gain broad support from other faculty or their institution. Consequently, another guiding principle of our efforts was to seek faculty buy-in and support from the outset, both to gather needed information and to provide a larger group of faculty with the opportunity to help shape the content and character of the program. One reason this was critical is because the EIC initiative requires enthusiastic faculty to teach the new courses and to provide helpful insight and suggestions for infusing contextual content into the four- year curriculum. The approach that was used to gauge faculty support was a series of small group meetings and a follow-up survey. What we learned is discussed in the section on faculty buy-in.

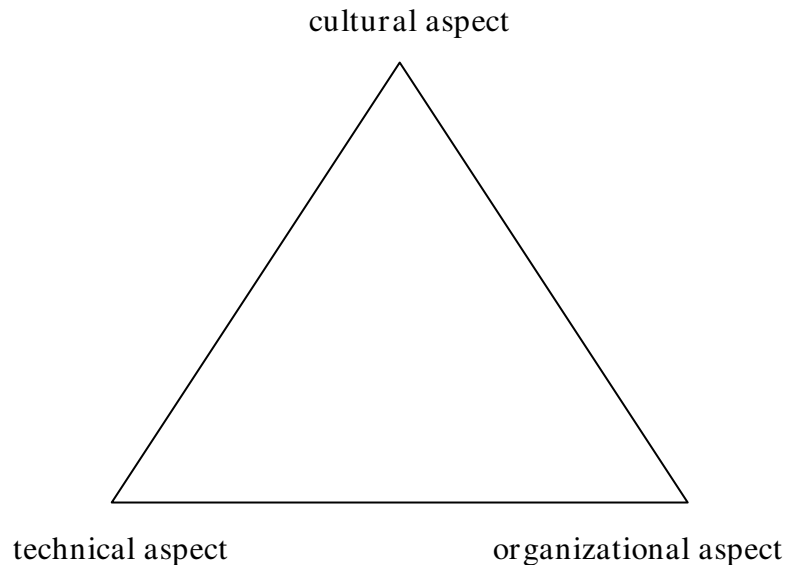
### The Engineering in Context Philosophy

The strategies and principles outlined above allowed us to develop what might be called the “engineering in context philosophy,” an approach that is presented to the students in ENGR 302 and that permeates the curriculum design for all four years. The engineering in context philosophy is that any successful set of technology-related activities can be understood as consisting of three highly interrelated components: the technical aspect, the cultural aspect, and the organizational aspect. (The cultural and organizational aspects to combine to form what is usually referred to as “societal context.”)

The concept of the triangle of technology practice, which we term the “EIC triangle” for the purposes of our program, comes from Arnold Pacey’s 1983 book, *The Culture of Technology* (MIT Press). The concept is illustrated in the figure below. The triangle helps students focus on the big picture and helps them locate and integrate the technical components and expertise with which they are most familiar within the larger contexts provided by organizations, culture, and other technical components or bodies of knowledge.

#### PACEY'S TRIANGLE OF TECHNOLOGY PRACTICE<sup>4</sup>

*Identifying the larger network of which a particular technology is a part. . .*



Examples of technology-related practices include systems of transportation, energy production, communication, medical treatment, national defense, manufacturing, and agriculture. The technical aspect, which is primarily material, consists of tools, machines, natural resources, wastes, and products, along with the knowledge, skill, and technique pertinent to using or transforming materials. The organizational aspect, which is primarily institutional, consists of entities such as business and government, unions, professional societies, schools and universities, and other institutions designed to get things done. The cultural aspect, which consists mostly of people's beliefs, includes such things as values, goals, ethical codes, assumptions, perceptions, symbols, images, aesthetics, and worldview.

For the example of transportation, the technical aspect would include knowledge of aerodynamics, internal combustion engines, paving techniques, oil, and electronics; the organizational aspect would include automobile manufacturers, auto workers unions, gas stations, departments of transportation, laws regulating speed limits, highway taxation; and the cultural aspect would include the prestige associated with certain kinds of vehicles, the value placed on individualism and independence, the belief that individual automobiles should be the dominant form of transportation, and the ethical proposition that driving while impaired by drugs or alcohol is wrong.

To view a particular engineering problem or undertaking in context, then, is to consider its technical, organizational, and cultural elements as an interconnected system. To understand a problem completely, one would need to explore all three aspects. Similarly, to map the requirements of a complete solution or successful implementation of a new technology, one would need to address all three aspects. The EIC triangle provides a big picture view that makes the organizational and cultural elements easier to identify and potential ethical issues and unintended consequences easier to discern. It also helps students understand engineers and



technology as agents of change, and to borrow Joseph Bordogna's phrase, helps them to be sure that they are "doing the right things."

The "EIC Problem" – What's different about it?

Case studies, which immerse students in the details of an historical event or incident and thus teach by example, form the basis for modern teaching in business, law and medicine. Case studies are essentially contextual, and allow students to analyze actual events with all the advantages of a retrospective view. For example, students might study the Enron Corporation's management decisions prior to its downfall, and follow up by discussion of the reasons for this behavior and possible alternatives. However, such case studies typically do not involve open-ended problem solving (design) and thus fail to capture the essence of what engineering is about.

Design problems on the other hand, which are often used in engineering teaching, are open-ended (no single right answer and require creativity for their solution), but are purposely isolated from their context to allow students to focus on the application of analytical skills. The "egg drop" contest, concrete canoe, and robotic challenges are examples of engineering design problems. The early stages of problem identification and definition, which are so essential to the practice of real world engineering, and which are so critical to the responsible and ethical direction of technological progress, are omitted. Students also have little or no connection to real applications and the impact their decisions might have on others at the community, social, and cultural levels.

EIC problems are those that combine engineering design and decision-making with real world context. The context may be based on historical fact, as for traditional case studies, or may be artificially created or virtual. The application of analytical skills, disciplinary knowledge and team and project management are emphasized in a cultural, organizational, and technological context. Design decisions are evaluated not only for their contribution to technical success (meeting stated performance objectives), but also for their impact on the various stakeholders, people and organizations, who stand to be affected by them.

Examples of EIC problems, taken from the current pilot EIC program at UVA, are the Oncoming Train Alert System (OTAS) and Smart Pill Bottle. The OTAS problem is the excessive fatality and injury rate among railway workers in the United States. Stakeholders include the workers themselves, their unions, railway management, stockholders, insurers and communities. The Smart Pill Bottle project is focused on the problem of inadvertent overdose and misuse of prescription medications, often a consequence of the inabilities of older patients to organize and administer their own medications. Both of these problems require open-ended design, but this must take place in the context of significant ethical, cultural, and organizational aspects. Throughout the program, we emphasize a process that is concerned not with defining projects but with solving engineering in context problems.

ENGR 302: Engineering in Context Course Content

The pilot course entitled "Engineering In Context" (also referred to as ENGR 302) has both philosophical and pragmatic objectives. On the one hand, reading assignments and class

discussion focus on the earliest phases of open-ended problem solving, namely the identification and definition of problems, and on the aftermath, i.e., the impact of engineering solutions on society and culture. It is important for students to grasp the importance of these earliest, formative stages in understanding the role of engineers in the evolution of technology and society, and their responsibilities for ethical and moral decision-making. On the other hand, ENGR 302 provides students with practical experience of proposal writing, project design, and team building. It also helps to prepare them in advance for the undergraduate thesis experience in the fourth year. While the syllabus for ENGR 302 appears as Appendix A of this paper, the following are the key themes and objectives of the course.

### Themes and Objectives

Students who have completed ENGR 302 should understand and be able to apply the following concepts/skills:

- critical thinking about the process of problem definition; problem definition as a research process, a creative process, a social process, and technical process
- the need for problem oriented (vs. project oriented) approaches to engineering design
- an integrated (vs. fragmented) view of technological systems
- the interactions among the technical, organizational, and cultural dimensions of engineering practice
- how aspects of cultural context (i.e., shared values, changes in widely held beliefs, or changes in political and economic environment) provide an impetus to technological development and provide engineering designers with new directions for technology
- how ethical and professional ideals and economic factors function not only as constraints but as sources of creative impetus and meaning for engineering design
- examination of prior art as an important part of the context of engineering design
- orientation to the undergraduate thesis project, including requirements and deliverables and the group project/individual thesis

### Activities and Deliverables

The course requires a series of relatively short reading and writing assignments, all aimed at helping students understand the various aspects of context and the process of problem definition. Most readings are case studies, allowing students to view, in retrospect, the process and consequences of engineering problem solving in which contextual aspects were either neglected, misread or successfully incorporated. Most classes are organized as discussions of the assigned readings. The major assignment for the course is to generate a proposal in which a significant problem is identified, a persuasive case is made for its solution, an analysis of context is developed, and a project management plan is provided. As mentioned earlier, successful proposals (approximately 30% of those submitted) are awarded funding for a senior year design and development project. Projects may be proposed by both individuals or small teams. For the initial pilot offering of ENGR 302, seven proposals were selected to be carried forward into the

2003-2004 academic year. Those senior level, capstone design projects are described in Appendix B.

## ENGR 401/402: Multidisciplinary Team Design and Development I and II Course Content

A two-course sequence entitled “Multidisciplinary Team Design and Development I and II” (MD&D), designated ENGR 401/402, is intended to provide students across all departments within the School of Engineering and Applied Science an opportunity to engage in a multidisciplinary, year-long, capstone engineering design and development project. The two courses are based on an engineering studio format, in which faculty meet and work closely with small groups of students (typically a 4 to 6 person team) at least once per week. The primary role of the 401/402 instructor evolves during the course sequence; initially, he or she is an instructor, providing the necessary project management techniques and methods of professional engineering practice. The role of instructor gives way, however, to one of mentoring, ensuring that students are seeking and obtaining the technical support (human and material) they need, helping to resolve administrative and technical issues that arise, and ensuring that students follow a disciplined engineering design process. Close coordination of objectives and assignments with the Science, Technology and Society course sequence (STS 401 and 402) helps to broaden the context within which the engineering design activity takes place and to guide students in exploring contextual aspects of their own problem and proposed solution.

It is important to note that, while many MD&D students will have completed the ENGR 302 course in the spring semester of their third year, ENGR 302 is not a mandatory requirement for the MD&D I/II capstone sequence. Project leaders from the ENGR 302 EIC course may recruit team members who did not take ENGR 302, but who would enhance or provide appropriate functional balance. A continuous support effort is provided throughout the MD&D I and II sequence by faculty and industry mentors for each project team. Each team’s effort culminates in the fabrication and verification testing of each team’s prototype product. A final team report and presentation of each project, including a product demonstration, is required.

### Objectives

The key objectives for the ENGR 401/402 sequence are:

- to provide students with a contextually realistic, multidisciplinary team engineering design and development experience
- to demonstrate that a successful project to develop a new product or process must consider the contextual aspects of technology, organization, and culture
- to introduce and demonstrate project planning and management tools and to show how these are essential to ensure successful project completion on time and budget
- to introduce students to the level and types of documentation required to define a new product/process and to demonstrate its importance as engineering’s principal “product” at the end of a development project
- to demonstrate the role and extent to which research and analysis are important prior to fabrication or production

- to introduce students to the importance of carefully defined and maintained product requirements, product specifications, engineering configuration management, and detailed test planning to verify that a new product meets its stated requirements

The syllabi for both ENGR 401 and 402 are included as Appendix C.

### Activities and Deliverables

The two-course sequence, ENGR 401 and 402, corresponds roughly to the activities of design and development, respectively. Capstone teams are expected to have completed the product design process by the conclusion of ENGR 401. Students then develop, build and test their designs during ENGR 402, culminating in a final prototype demonstration and written user's manual. It is expected that by the end of the Fall semester the teams will have completed the following:

1. Product Requirements Document (Specification)
2. Concept Selection Rationale: Sizing Analysis, Modeling and Trade Off Analyses
3. Preliminary Design Review
4. Fabrication and Verification Test Schedule
5. Fabrication and Verification Test Budget
6. Program Review

Each of these is a written assignment, though it is understood that the Product Requirements document evolves with the team's understanding of their problem and its solution, and will require periodic evaluation. The semester culminates with the Final Program Review where each team presents their final design to a panel (typically consisting of faculty advisors and industry sponsors or representatives). Teams are expected to explain and defend the details of their design and their design rationale. Successful completion of the Program Review then launches the fabrication and test phase of the project that is the subject of MD&D II (ENGR 402).

In addition to a final prototype demonstration, teams are required to produce final documentation at the end of ENGR 402, including an engineering log book, operational instructions (user's manual), a bill of materials, parts drawings, specifications, procedures, and product/process test reports.

### Faculty Buy-In

As mentioned earlier, achieving faculty buy-in was a very important objective for the pilot phase of the EIC program. This section describes the approach we took to achieving this objective. Our approach had two key elements:

1. Select members of the SEAS faculty were invited to discussion sessions explaining the EIC initiative, its purpose and objectives, and planned implementation and exploring both the potential and problems of implementing the initiative.

2. Each faculty member who attended an information session was invited to complete a faculty buy-in survey.

Approximately thirty faculty members from across all departments within the engineering school attended one of two meetings held to present the Engineering in Context initiative and to solicit their views and suggestions. In addition to discussion, both during and after the meetings, a survey questionnaire was sent to each participant. The results of our discussions and analysis of the survey indicated overwhelming agreement among faculty that undergraduate engineering education does present a discrepancy between the practice of engineering and the way we teach. Their responses also indicated near unanimous support for the importation and integration of *context* as a promising approach to redirecting the course of undergraduate engineering education. We found that the two issues of greatest concern were: (1) lack of faculty resources and support for multidisciplinary experiences integrating theory and practice, and (2) how to teach engineering in context in a way that is both rigorous and substantive.

Most engineering educators are well aware of the advantages of reinforcing concepts with concrete examples, hands-on experiences such as a senior-level capstone project, multidisciplinary teamwork and design, open-ended problem solving and interactive discussion, but they are also well aware of the time and infrastructural and institutional support needed to integrate these into their teaching. A successful initiative must address these issues. It must recognize that at institutions becoming increasingly dominated by research, faculty are often left unrewarded for taking extra initiative in teaching, especially at the undergraduate level. In fact, they may end up being penalized for the extra time and effort invested.

Institutional recognition and incentive to motivate faculty to introduce the needed reforms are essential. Faculty hires at engineering schools dominated by research emphasize demonstrated potential for scholarly research, with much less weight attached to engineering experience, know-how or teaching ability. In fact, many faculty members at engineering institutions have little or no real engineering experience and do not feel comfortable teaching engineering practice. To counter this trend, an increasing number of institutions have begun to turn towards “professor of practice” faculty positions to attract experienced professionals to teaching, thereby importing the practice and context their science-oriented faculty lack.<sup>5</sup>

Regarding the second major issue, some faculty expressed doubt that they would know how to go about developing and integrating context in their classroom teaching. Others indicated lack of confidence that they would be able to integrate context without sacrificing disciplinary depth (rigor) or content. One implication here is that institutional support and training are needed to develop contextual teaching ability and confidence. Another is that further study is needed to develop contextual teaching methods that can support rigorous and substantive disciplinary teaching. On the other hand, some faculty responded that they already integrate context into their classroom experience and that the most successful teachers know, instinctively, that learning and retention are improved when students are shown connections between newly acquired knowledge and real world examples. Such “natural resources” should be cultivated and encouraged to create the kind of contextual engineering education experience we feel is needed.

## Curriculum Assessment and Evaluation

At the time of writing, the first group of EIC students were completing the final semester of the program. A second group began the three course sequence in January of 2004.

We decided at the outset of program development to develop and employ objective evaluation and assessment of the courses to judge the efficacy of the EIC pilot initiative. This is extremely important to assure an ongoing reflection and improvement program. Certainly, the first offering of the courses will not be totally satisfactory and will require modification. To address this objective, we utilized two university sponsored resources: (1) a standard student course evaluation survey and (2) the Teaching Resource Center (TRC), whose trained, objective, and impartial researchers conducted a special review session with the ENGR 401 class to determine whether the objectives of the course were met. Each of these surveys, the individual student survey and the Teaching Resource Center review, is discussed below.

The TRC assessment activity was designed to measure the outcomes of the EIC course sequence against the EIC course objectives. As discussed earlier, the objectives of the course sequence are:

1. to prepare students to make a more immediate contribution to an engineering project by exposing them to the organizational and team-based culture, cost/performance issues, regulatory environment, and systems-based approaches, that characterize industry projects,
2. to prepare students to assume leadership positions by orienting them to the social, economic and ethical environments in which technology development occurs,
3. to stimulate resourcefulness and creativity by providing design/build experiences that result in the creation and development of a product or process.

The expected outcomes of the EIC course sequence are for the students completing the design projects to have:

- demonstrated a knowledge of relevant materials and processes
- demonstrated creativity
- incorporated economic and cost considerations in their designs
- addressed relevant regulatory codes, including safety and environmental considerations, in their design
- incorporated marketing and public acceptance issues in their designs
- addressed the social impacts of their designs
- addressed ethical and justice considerations raised by their designs

The assessment process posed four questions to the class in an open forum venue. The consultants led the discussion, collected the resulting comments and formulated them into a summary report.

The results of this assessment suggest that the EIC program is achieving its central goals. The results also highlighted several areas for improvement, which are being incorporated in the program for the spring 2004 semester.

The following summarizes student responses to each of the four TRC questions:

1. What do you feel that you have learned?

- to work with multi-disciplinary teams
- to write a technical proposal
- the level of detail required to develop a product
- the discipline required for the product development process
- consideration of non-technical aspects of engineering
- how long it really does take to get a project going

Our review of the student responses indicates an appropriate understanding of the power of collective wisdom spawned by the dynamics of a multi-disciplinary team, the importance of defining the “real problem,” the need for an in-depth analysis of the EIC aspects of the real problem, the importance of a disciplined design and development process and the importance of detailed and quality engineering documentation. These take-away points from the assessment process provided us with a good, albeit a subjective, feeling that the students have achieved an appropriate understanding of the real world design and development process.

2. What most helps your learning?

- availability of instructors
- interactive group meetings—not a lecture format
- actually doing something
- a more real life experience—with funding to manage and outside of the university contacts

Our review of these student responses indicates that the individual team/instructor meetings provide a positive and interactive teaching format that simulates a more real world project team situation where the instructor interacts much as would a real world program manager. Further, the teams are empowered to pursue their project needs independently, which simulates a real world situation. They must manage a budget and schedule; define, negotiate and procure necessary project material; and maintain an open line of communication with their customer/client. Their experiences have been sometimes frustrating, confusing and inefficient, but always very real world. The morale of the teams has been excellent as they feel empowered and self-directed. The teams feel that they are actually “doing something” by designing and prototyping a unique product.

3. What most impedes your learning?

- not having enough time and too many assignments
- not having solid examples of required documents
- readings not very helpful
- tension between creating document and designing the product

Our understanding of these comments is three fold. First, senior level students are very busy and in some cases overwhelmed with work, which is generally the norm and not a reason to modify the course sequence. Secondly the course requires a significant amount of documentation for which, by design, detailed examples were not provided to the students. The instructors discussed the content of each document and provided example outlines to the teams. This approach was chosen to foster student creativity and to urge them to pursue independent research. In retrospect and going forward, we believe that we should, after the students have created a first draft, provide them with a sample of the required document. Thirdly, the textbook readings were not considered worthwhile by the students. The text readings were covered very quickly and at the beginning of the ENGR 401 course provide the students with an understanding of the text material and to encourage their independent reading of the material as necessary. Examples of engineering documents and trade-off analysis were covered by the text. It is felt that the text is an important reference and will be used going forward.

#### 4. Suggestions/Improvements

- define due dates more clearly and spread out documentation
- provide earlier and more detailed feedback on documents
- facilitate more interaction between all the teams
- have more actual companies come in to present the problems they are working on

Responses to these suggestions have been carefully discussed with the instructor team. We believe that it is important that the teams have an opportunity at periodic intervals to participate in a total class review of the status of all the teams. This provides the students with a relative understanding of what other teams are doing, their problems and experiences. While this is difficult to schedule, since it would require a block of at least three hours, it is important to provide. Also, while a significant amount of work for the instructors, it is also important to provide each team with a detailed review of their submitted documents.

The second approach, the individual student course evaluations, is a standard university process that allows all students to provide anonymous inputs to the university and the student's instructors on the effectiveness of the instructor and the benefits of the specific course.

Based on the course evaluations, the ENGR 302 students believed:

##### 1. negative aspects

- the level of effort required was too great for a one credit course
- the proposal assignment should have been started sooner in the semester
- the reading assignments were of questionable value



## 2, positive aspects

- the technical, organizational, and cultural discussions were excellent
- the class was well organized and interesting

Our analysis of these responses resulted in a number of changes to ENGR 302; specifically, we now start the proposal process earlier in the course and review the relevancy of all the assigned reading material more closely. However, in most cases, we feel that the reading material and the course level of effort is appropriate and the comments to the contrary are somewhat typical and not significant for change.

In summary, the ENGR 401 students believed:

### 1. negative aspects

- the course was rather unstructured with not enough handouts providing examples of the required documents
- students would like to have more interaction with the other teams

### 2. positive aspects

- great class concept
- think the EIC concept a success
- flexible and adaptive to change and student input

Review of these responses resulted in agreement on the need for creating more interaction between teams and to provide better examples of the required documents, but not until after the students have submitted their first draft of the document. We further felt that the students fully grasped and supported the EIC concept and the importance of considering the contextual aspects of a problem as part of the disciplined design and development process.

## Instructor Reflections

Real team teaching—that is, having all three members of the team involved in planning and conducting all classes—is central to achieving the integration of qualitative and quantitative aspects that the engineering in context philosophy embodies. The experience has been transformative for the faculty involved. Although we envision that the course will not be taught by teams of three in the future, we do anticipate retaining the team approach because of the diversity of perspective that it provides.

Not all case studies or problems drawn from industry present students with genuine engineering in context problems, that is, problems in which the kinds of constraints specified in Criterion 4 are clearly present and experienced as significantly influencing the design and problem-solving process. In order to improve upon the type projects selected for funding and development, it will be important, going forward, to develop a greater number of outside the university resources for problems and to serve as customer/clients for the teams.

The organizational aspect of the EIC triangle is crucially important, but many university faculty members have either limited or no direct experience of the organizational dimensions of engineering practice. This means that faculty with extensive industrial experience are crucially important for helping students understand the “real world” aspects of their projects. These faculty members, who might be called “professors of practice,”<sup>5</sup> will likely find themselves in great demand in programs like ours. Similarly, industrial sponsors are crucial for providing a realistic sense of context.

The effort required of the instructors, particularly in mentoring the teams, is significant and requires a broad understanding of varying technologies. Each team meets with its faculty advisor/instructor for over one hour once a week. Additionally, some individual team members meet with their faculty advisor/instructor for weekly one hour meetings. This can mean over four hours of meetings per team per week. If an instructor has three teams (as is the case with one of the ENGR 401/402 faculty), this means at least 12 hours of meeting time. Additionally, the instructor must become knowledgeable of each of the three different team problems and technologies and make recommendations for research and references while commenting and grading their work products. The advisor/instructor must work both as a program manager and technical advisor.

The students, while somewhat overwhelmed, are gaining an important real world design experience, while still within the friendly confines of the university. They have been empowered to pursue their problem of interest and must deal with the real world frustrations of cost, schedule, and failure. They have learned that supplier documentation is not always adequate and that supplier material may not be of appropriate quality. They have learned the importance of planning, analysis, and documentation as important steps in a successful engineering development project. They have learned that engineering is making trade-offs between alternatives based on detailed selection criteria. They have learned the importance of communication between team members, suppliers, and customers and that obtaining timely and complete answers to questions from customers is difficult, but very important.

The EIC curriculum can be improved. With the inputs from the students and the Teaching Resource Center we have a good understanding of the necessary steps for improvement. The improvements are straightforward and are being incorporated into the follow-on course offering.

In summary, our assessment efforts to date lead us to believe that the students have achieved a basic understanding and appreciation of the realistic constraints of a real world design and development project, whereby the considerations of economics, environment, manufacturability, ethical, safety, and social and political dimensions are critical to the project’s success. These considerations are the contextual aspects that form the philosophical umbrella over the University of Virginia’s Engineering in Context initiative.

## Conclusion

The governing tenets of the EIC initiative that were established at the outset were carefully managed and assessed. The pilot program has adhered to these tenets and the EIC initiative has:

1. Provided a real world senior level design experience involving industry partners—accomplishing the Lockheed-Martin objectives.
2. Integrated the organizational/cultural/societal aspects of a new product development that are important to the success of the evolving contemporary engineering leader.
3. Provided a multidisciplinary team design experience that provided autonomy, authority with responsibility, and interaction with industry sources outside the university.
4. Met the requirements as delineated in ABET 2000 Criterion 4 and supported the SEAS strategic plan.
5. Supported the traditional senior thesis requirement providing appropriate course credits.
6. Achieved faculty buy-in and provided meaningful assessments of the EIC course sequence effectiveness

Programs like EIC place great demands on everyone involved, but they seem worthy of the investment. Exposing students to the context of engineering and helping them understand themselves as agents of change can (a) prepare students more effectively for professional practice, (b) enhance student motivation, and (c) benefit society at large through projects that “do the right thing.” A confluence of such factors is rare, and it suggests the potential of the engineering in context approach.

#### Acknowledgement

We wish to acknowledge the support and oversight provided by Lockheed-Martin Corporation as significant to the success of this initiative providing both funding for the pilot program and active participation in the review and development of the curriculum.

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#### Biographical Information

KATHRYN A. NEELEY is associate professor in the Department of Science, Technology, and Society in the School of Engineering and Applied Science at the University of Virginia.

DANA ELZEY is associate professor of Materials Science and Engineering in the School of Engineering and Applied Science at the University of Virginia.

DAN BAUER is adjunct professor of engineering in the School of Engineering and Applied Science at the University of Virginia. He has many years of industrial experience..

PAXTON MARSHALL is Associate Professor of Electrical and Computer Engineering and Assistant Dean for Undergraduate Programs in the School of Engineering and Applied Science at the University of Virginia.

# APPENDIX A

## ENGINEERING IN CONTEXT (ENGR 302):COURSE SYLLABUS

### 1.0 Class Dates and Time

Friday, 1:00 pm to 2:15 pm  
First Class, January 16  
No Class, March 12, Spring Break  
Last Class, April 23  
Class Room: D223, Civil Engineering Building

### 2.0 Instructors

- 2.1 Professor Kay Neeley, Technology, Culture and Communication, [kan8v@virginia.edu](mailto:kan8v@virginia.edu),  
Office A224, Thornton Hall, 924-6117  
2.2 Adjunct Professor, Dan Bauer, Engineering, [dob6n@virginia.edu](mailto:dob6n@virginia.edu), Office C243, Electrical  
Engineering Building, 964-4681

### 3.0 Description and Objective

Engineering in Context (EIC) introduces students to aspects of professional engineering practice which are critical in defining the role of modern engineers within their multi-disciplinary, time- and-cost driven environment. The course will utilize readings and case studies to illustrate the constraints on engineering, other than those imposed by purely technical considerations, such as cost, safety, environmental impact, quality of life, etc.

The objectives of the EIC course are:

1. to provide you with a realistic and contemporary understanding of the practice of engineering,
2. to enhance your understanding of the larger context of engineering practice, especially the cultural and organizational impact of technology and the responsibilities of engineers to the society they serve,
3. to help prepare you for a multi-disciplinary, team product/process design and development experience during your fourth year (TCC/ENGR 401/402 sequence), and
4. to provide guidance in developing your senior thesis.

### 4.0 Course Design and Requirements

Like other courses you have taken, this course will provide you with new knowledge, knowledge of important contextual aspects of modern engineering practice. But, unlike many of the courses you have taken, it is also designed to engage you in processes and experiences that will help you develop the skills and abilities you will need to apply your knowledge in the “real world”.

Specifically, this class is designed primarily as a seminar rather than as a lecture class. One of the key features of a seminar is that students learn from each other as well as from the instructors. Class discussions, especially discussions of assigned articles and case studies, will be an important part of the class. These discussions will provide a forum for developing your communications skills as well as the opportunity to explore the significance of the material presented in the course.

Consequently, class participation is a large part of the grade for this course. We will provide guidelines for participating effectively, but the key is coming to class well prepared and making an effort to contribute to a quality outcome for the discussion in question. Of course, you can't participate if you aren't in class, so attendance is also very important.

The students, individually or teamed, will be required to write and submit a proposal identifying an engineering challenge or problem and a concept for an engineering solution(s). The proposal should persuasively present the significance and the implications of the proposed solution. Successful proposals will be granted a small amount of funding and the opportunity to build an engineering design team to pursue their concept through design, development, build and demonstration during the senior year ENGR 401/402 courses.

## 5.0 Overall Course Structure

### Module I: Course and Syllabus Overview:

- Introductions
- EIC philosophy and Lockheed-Martin involvement
- Objectives of the class
- Class schedule, pass/fail grading and participation guidelines
- Proposal assignment discussion

### Module II: Technical, Organizational and Cultural Aspects of Engineering In Context

- Defining the three aspects
- Contextual factors imposed on the practice of engineering
- Stakeholders and consequences

### Module III: Problem Definition and the Creative Process

- Critical thinking—"Out of the Box"
- What is the real problem?
- Problem conversion to design requirements
- Multidisciplinary teams and concurrent engineering

### Module IV: Proposal Development

- Writing a winning proposal
- How to manage constraints and issues
- Project development plan
- Proposal review and selection process

### Module V: Project Team Development

- Team building
- Resource requirements and allocation
- Project management

### Module VI: Preparation for ENGR 401/402

- Thesis requirements overview
- Summer plans

## 6.0 Grading

Grading for this class is pass/fail. In order to pass the course, you must complete all of the required assignments for the course at a professional level. Criteria will be established for all assignments.

The required assignments are as follows:

1. Class Participation, including readings and brief written assignments to prepare for class discussions.
2. Written Proposal, including outline and drafts
  - Due April 9
  - Selection of “winning proposals” completed by April 16
3. Final Examination

## 7.0 Text and Reference Material

There is no required text book. Reference reading will be assigned and select material will be posted on the class toolkit (ENGR302-1).

## 8.0 Communication, Class Etiquette and Administrative Details

You are expected to attend all classes and participate in class discussions. You are expected to arrive for class and be seated at the time class is scheduled to begin. You are responsible for obtaining all applicable course material that you may have missed as a result of being late or absent.

When you must be absent, please inform one of the course instructors, preferably in advance of the absence, either by email or telephone. If you have any questions or require information concerning the course, please contact either of the course instructors either by email or telephone. If you wish to meet with one of the instructors please contact him or her, either by email or telephone to set up a convenient meeting time and place.

You will be informed, prior to each assignment, of the required format and whether a hard copy or electronic media copy of the assignment is required. Late assignments will be penalized at the discretion of the instructors.

All students, unless otherwise specified, shall pledge all individual work in accordance with the UVA honor system.

## APPENDIX B

### Engineering in Context Multidisciplinary Design Projects

Spring 2003-Spring 2004

#### Automated Oncoming Train Notification System

Currently, each year hundreds of railroad workers are getting struck by trains and either killed or injured due to the fact that they did not have sufficient warning that there was an oncoming train. The current notification systems have many gaps, and we propose to implement a system using the GPS already installed on each train to notify each individual worker through a device similar to a pager.

#### Relevant Majors/Minors:

Electrical engineers interested in wireless communication

Systems engineers to help with communication between the engineers and the customer and to also help with the overall design of the system

Contact Person: Sarah Cary

E-mail: slc8r@virginia.edu

#### Automated Solar HVAC Management System

The objective of this project is to design an automated solar energy management system for UVA's Solar House. The house is designed for a combination of passive and solar heating. The current HVAC system has enormous potential; however, rigorous analysis, both theoretical and experimental, has yet to be completed in order to optimize and effectively manage the system. The plan calls for installing temperature sensors within the house, updating the present LabView data-logging device, creating algorithms and codes for decision-making processes, installing the necessary controls for automation of doors and drapes, and using a simulation program to analyze the efficiency of systems within the house.

#### Relevant Majors/Minors:

Chemical Engineers with thermal analysis and simulation expertise

Mechanical Engineers for the automation process

Electrical Engineers for data logging and LabView codes

Systems/CS for updating website periodically

Contact Person: Ana Ramcharan

E-mail: acr6g@virginia.edu

#### Bus Accident Detection System

This project involves designing and implementing a prototype system that can detect and report bus accidents. At the University Transit Service, all accidents are supposed to be recorded, and damage claims are submitted to an insurance provider. UTS has lost significant amounts of revenue repairing damage caused in accidents that were not reported properly, so a system is needed that reports accidents whether



drivers want them reported or not. This system will use inexpensive sensors on body panels of the bus, GPS technology, and wireless data communication technology.

Relevant Majors/Minors:

Electrical engineer to lay out the conceptual basis for the sensor circuit design

Systems engineer for integrating the various technologies

Computer science to design rudimentary data reporting and storing procedures

Materials science for selecting a material for the sensor system.

People with expertise in GPS and wireless technologies would be helpful as well.

Contact Person: Peter Ohlms

E-mail: pbo5d@virginia.edu

### Nuclear, Chemical, and Biological Communications Network

The threat of nuclear, chemical and biological (NBC) weapons is ever increasing. Effective methods for detecting NBC's remain underdeveloped while their potency and proliferation continue to climb. The objective of this project is to build and test a prototype of a communications network, which will connect existing NBC legacy sensors to a base station receiver. The receiver will interpret and present data collected from the sensors, allowing the user to make informed decisions.

Relevant Majors/Minors:

Electrical Engineer with knowledge of power consumption and designing communications electronics (radio frequency transmission and Ethernet)

Mechanical or Material Science Engineer to design the receiver box to fit required specifications (height, weight, etc.)

Computer Engineer or Computer Science with knowledge of communications protocols, networking, and data transmission

Other majors with relevant skills and interest in the project

Contact Person: Ryan Dickey

E-Mail: rkd5v@virginia.edu

### Pharmaceutical Prescription, Distribution, and Self-Organizing System

The misuse of prescription drugs may be the most common form of drug abuse among the elderly. Elderly persons use prescription medications approximately three times as frequently as the general population and have been found to have the poorest rates of compliance with directions for taking a medication. Clearly, there is a need to improve and simplify the prescription, distribution, and use of medications. We propose a medicine Prescription, Distribution, and Self-organizing (PDS) system that will authenticate all prescriptions, eliminate incorrect or fraudulent distribution, and decrease the risk to the patient. Such a system would save lives every year. Currently, a patient receives a paper prescription from a medical professional and takes the prescription to a pharmacy. The pharmacist will then distribute the medication with literature on the particular drug. The first problem with this system is the transaction method. Our system will secure the prescription system by electronically encrypting prescription information on smart cards and authenticating all transactions. The other major problem that our system addresses is drug misuse. By placing wireless sensors on medication

bottles, patients can physically place bottles together to determine the safety of use. The wireless sensors will automatically detect any dangerous combinations and alert the user. In addition, inexpensive LCD displays will be available to access product information, which is also stored in the sensor package.

Relevant Majors:

Electrical or Computer Engineer to design and implement the sensor package for the pill bottles. Computer Science or Computer Engineer to develop Simulation software for the prototype system; we need an engineer with experience in computer simulations and graphical interfaces. Mechanical Engineer with experience in the area of materials science to develop the physical pill bottle, as well as an attachment mechanism for the sensor package.

Contact Person: Spence Green

E-mail: wsg6f@virginia.edu

**Private, Personal, and Convenient Identification using Biometrics**

There are no inexpensive means of efficiently verifying the identity of an individual, which potentially allows illegal immigrants to enter the country, terrorists to attack America, and rampant credit card fraud and identity-theft. This project will use biometric data that is unique to a specific individual (such as the individual's fingerprints, iris, hand, facial, and voice patterns) to achieve accurate personal identification. The goal of the project is to produce a working prototype of a typical checkpoint that would be used in the system. One key feature of the proposed system is that it will protect the privacy of the individuals using it. To maintain a high level of privacy, no data will be transmitted to or stored in a main database system, thus effectively blocking the ability of an individual or organization to obtain information about any of the system's users. The project is seeking individuals who are interested in biometric identification and possess either strong programming skills (C++ and/or C#) or the ability to analyze societal impact and acceptance.

Website: <<http://www.jason1365.com/ThesisProjectProposal.php>>

Contact Person: Jason Lund

E-mail: jason1365@virginia.edu

**Versatile Mobile Reconnaissance Device**

The Versatile Mobile Reconnaissance Device (VMRD) will be designed as a small, versatile and mobile robot that can save lives in urban combat, in the event of biochemical weapons attack, and in numerous hazardous jobs. One use case is for local law enforcement. A police officer performing an arrest in a known drug house would be able to throw a VMRD through a window of the house to survey the layout and tactical positions of its occupants. The VMRD could also aid a field agent of the Environmental Protection Agency inspecting a building contaminated with anthrax. He would be able to move the VMRD through the air vent tunnels and take anthrax level readings of the entire building without stepping foot in the actual building. These are just two of the numerous scenarios that a VMRD can be used to save human life.

Relevant Majors:

Mechanical Engineering for mobility design and expertise in Robotics

Material Science or Mechanical Engineering for durability and shock absorption design

Computer Science, Computer Engineering, or Electrical Engineering for remote control and wireless communication design

Systems Engineering, Computer Science, or Computer Engineering for design of an easy-to-use user interface design

Contact Person: Chris Han

E-mail: [chrishan@virginia.edu](mailto:chrishan@virginia.edu)

## APPENDIX C

### ENGR 401: MULTIDISCIPLINARY TEAM DESIGN & DEVELOPMENT I

#### SYLLABUS

##### 1.0 Class Dates and Time

Monday and Wednesday, 3:30 to 4:45 PM\*\*

First Class, August 27

Last Class, December 3

Class Room, Olsson Hall 011

Team Meeting Room(s): Prof. Elzey—Office MSE 319,  
Prof. Bauer—Office EE C243

\*\*Team Meetings will be scheduled at appropriate and convenient times to coincide with text readings and project milestones. These meetings will most likely not occur at the published class time or be consistent week to week however, it is anticipated that each team will meet at least once per week with its faculty coordinator.

The entire class will meet periodically, as appropriate for project status and general lectures. These class meetings will be at the published class time of 3:30 to 4:45 PM and in the published classroom unless otherwise notified.

##### 2.0 Instructors

2.1 Professor Dana Elzey, Materials Science and Engineering,  
[dme2j@virginia.edu](mailto:dme2j@virginia.edu), Office 303, Materials Science Building, 982-5796 (Office)

2.2 Adjunct Professor, Dan Bauer, Engineering, [dob6n@virginia.edu](mailto:dob6n@virginia.edu),  
Office C243, Electrical Engineering Building, 964-4681 (home)

##### 3.0 Text

3.1 Product Design and Development, Karl Ulrich and Steven Eppinger, McGraw-Hill

3.2 Supplemental Readings, e.g. ISO 9000 Requirements

##### 4.0 Description and Objectives

ENGR 401 is the first semester of a two semester multidisciplinary capstone design sequence, in which student teams are provided the opportunity to implement the projects proposed in ENGR 302. ENGR 401 is a three credit course. The follow-on course in the sequence, ENGR 402, is also a three credit course.

A disciplined design process will be followed that incorporates the important activities of: problem definition, customer needs definition, concept generation and selection, product specification, modeling and analysis, proof of concept prototyping, design verification, cost analysis, and project management and scheduling.

Throughout the design process emphasis will be on quality management, concurrent engineering, creativity, leadership development and societal enhancement and impact analysis.

ENGR 401 will be coordinated with TCC 401 to provide a broadened context for engineering problem solving and enhanced awareness and melding of important social and cultural issues into the team development projects

The ENGR 302/401/402 sequence coupled with TCC 401/402 will provide each student with a coordinated and early start on their individual senior thesis projects. It is anticipated and acceptable that a student's thesis project be derived from the class team project. However, each student must generate separate individual thesis documents. This will require partitioning or allocating the team project work so that each team member has a definable and distinct technical focus for his/her senior thesis topic. ENGR 401 is planned and scheduled to facilitate the development of the student's senior thesis in concert with the requirements of TCC 401/402. For your planning purposes please reference the TCC 401/ 402 Senior Thesis Milestones attached as Appendix A.

The objective of ENGR 401 is to provide each student with a multi-disciplinary team experience in the design and development of a product. Also, each student will become practiced in and knowledgeable of the key activities and milestones and cross-functional aspects of a disciplined design process. The design process that will be followed will involve consideration and analysis of the contextual aspects of technology, organization and culture as they relate to product development and project management. These aspects form a part of today's contemporary product development process, were presented as part of ENGR 302, and will be practiced as part of ENGR 401 and the follow-on ENGR 402 course.

## 5.0 Topics and Requirements

It is expected that by the end of the Fall Semester the teams will have completed the following:

1. Product Requirements Document (Specification)
2. Concept Selection Rationale: Sizing Analysis, Modeling and Trade Off Analyses
3. Preliminary Design Review
4. Product Verification Test Plan
6. Fabrication and Verification Test Schedule
7. Fabrication Budget and Product Design to Cost Budget
8. Program Review Meeting

The semester culminates with the Program Review where each team presents all of their documentation, described above, to a select panel. The panel will critique the design and expect the team to explain and defend the details of their design and their design rationale. Successful completion of the Detail Design Review will launch the fabrication and test phase of the project that is the objective of ENGR 402.

Documentation will include an Engineering Notebook, Operational Instructions (User's Manual), Bill of Materials (BOM), Parts Drawings, Specifications and Procedures as appropriate.

## 6.0 Course Structure

Module I: Development Process and Economics Text Chapters 1, 2 and 15

Module II: Planning and Managing Product Development Projects, Text Chapters 3,16

Module III: Customer Needs, Product Specification, and Industrial Design, Text Chapters 4, 5 and 10.

Module IV: Concept Generation and Selection, Text Chapters 6 and 7

Module V: Product Design and Test, Text Chapters 8, 9, 11, 12 and 13.

## 7.0 Course Schedule

<u>Class Date</u>	<u>Module</u>	<u>Assignment</u>	<u>Place</u>
August 27	Intro	None	Olsson 011
Week 9/1	Module I	Text Ch. 1, 2, 15	
Week 9/8	Module II	Text Ch. 3, 16	
Sept 10		Project Review I and Project Work Allocation	
Week 9/15	Module III	Text Ch. 4, 5, 10	
Week 9/22	Module IV	Text Ch. 6, 7	
Sept 22		Product Spec and SOW	
Week 9/29	Module V	Text Ch. 9, 11, 13	
Oct 1		Concept Selection Rationale	
Week 10/6	Module V	Text 8, 12	

Week 10/13 (Reading Day 10/13, 14)	None
Week 10/20	None
Week 10/27	Preliminary Design Review & Proof of Concept
Week 11/3	None
Week 11/10	Project Review II—PDR Follow-Up
Week 11/17	None
Week 11/24	2004 Fabrication & Test Schedule
Thanksgiving Vacation 11/26—28	
Week 12/1	Program Review (Includes Verification Test Plan and Equipment Design)
Dec 9	Final Exam, 2:00 to 5:00 PM Reflections
	Olsson 011

## 8.0 Grading

Your course grade will be based on a 100 point scale. Individual team members will receive the team grade for team activities as noted. For other activities, where individual performance can be judged, individual grades will be assigned. Attendance and participation may be used as a factor in grading at the discretion of the instructors. It is strongly recommended that all students attend the Dec 9 Reflections sessions.

The points will be allocated as follows:

a. Project Review I	10 points	Individual
b. Product Specification	5 points	Team
c. Concept Selection	10 points	Team
d. Proof of Concept	5 points	Team
e. Prel Design Review	15 points	Individual
f. Verification Test Plan	10 points	Team
g. Project Review II	10 points	Individual
h. Fab & Test Schedule	5 points	Team
i. Detail Design Review	15 points	Individual
j. Documentation	15 points	Team

Drawings  
BOM  
User's Manual  
Specifications  
Procedures  
Engineering Notebook

## 9.0 Communication, Class Etiquette and Administrative Details

You are expected to attend all classes, team meetings and faculty coordinator meetings, and participate in team and class discussions. You are expected to arrive for class or team meeting and be seated at the scheduled time. You are responsible for obtaining all applicable course material that you may have missed as a result of being late or absent. When you must be absent please inform one of the course instructors, preferably in advance of the absence, either by email or telephone.

If you have any questions or require information concerning the course, please contact any of the course instructors either by email or telephone. If you wish to meet with your faculty coordinator, please contact him either by email or telephone to set up a convenient meeting time and place. You will be informed, prior to each assignment, of the required format and whether a hard copy or electronic media copy of the assignment is required. Late assignments will be penalized at the discretions of the instructor.

All students, unless otherwise specified, shall pledge all individual work in accordance with the UVA honor system.

### Addendum

#### Senior Thesis Milestones: TCC 401 and 402

##### Fall 2003: TCC 401

August 27 or 28 Statement of Topic due first day of TCC 401.

September 16 or 17 Pre-proposal due in TCC 401. This is a relatively short document briefly describing the EIC team project as that project has evolved and the problem and approach have been redefined over the summer. Expectation is that significant change will have occurred. All team members should briefly discuss how work might be allocated among the group and what they imagine their individual unique contribution to the group effort might be.

October 22 or 23 Proposal due in TCC 401. This 15pp. document develops the context and motivation for the team project, summarizes the literature review, presents a detailed work plan, and describes the intended outcomes of the team project.

October 23 thru End of classes Oral presentations of proposals in TCC 401 class

##### Spring 2004: TCC 402 (dates are approximate)



January 15	Progress Report due in TCC 402 class. By this time the focus of individual theses should be clearly defined.
February 15	Detailed outline and partial draft of individual thesis due.
March 25	Final draft of thesis due. Ideally, the final product of the individual thesis is a significant milestone/input for the final team product.
March 25 thru	Oral presentations of theses in TCC 402 class