

## **AC 2007-1382: REDESIGNING A COLLEGE-WIDE MULTIDISCIPLINARY ENGINEERING DESIGN PROGRAM AT RIT**

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# Redesigning a College-Wide Multidisciplinary Senior Design Program at RIT

## Abstract

Since 2002, the Kate Gleason College of Engineering (KGCOE) at the Rochester Institute of Technology (RIT) has seen its Multidisciplinary Senior Design (MSD) program grow from a small pilot project into a college-wide initiative, involving four departments and almost 400 students annually. While subtle adjustments have been made each year, a major redesign effort was undertaken prior to the 2006 academic year to improve program alignment with departmental objectives, to improve delivery efficiency and effectiveness, and to improve student and faculty satisfaction.

The project definition process was overhauled to focus on the definition of related projects within a set of disciplinary “tracks,” consistent with academic programs and faculty interests. Emphasis was placed on development of reusable and scalable platforms to lay the foundation for future project extensions, and to encourage cross-project and cross-department collaboration. To reduce startup time normally associated with student projects, day-long workshops were developed for the first four weeks that forced intense focus on customer requirements, engineering specifications, and concept development and selection. The workshop structure and format further encouraged collaboration within and across teams. Lastly, a Wiki-based online environment was created to support knowledge capture and emergent collaboration.

This paper provides an overview of changes to the MSD program in three key areas: course delivery, project definition, and communications infrastructure. Attention is given to innovative approaches to challenges inherent in serving a large and diverse constituency with limited resources.

## Introduction

Project-based “capstone” design has become an integral component of the undergraduate engineering experience. Howe and Wilbarger<sup>1</sup> surveyed over 400 programs in the 2005 National Survey of Engineering Capstone Design Courses, a follow-up to a comprehensive survey conducted by Todd in 1994<sup>2</sup>. Last year’s ASEE conference contained a number of papers on capstone design programs<sup>3-9</sup>, with many of them focusing on assessment practices and lessons learned. Important benefits associated with collaborative design projects include: innovative problem solving, improved handling of complexity and ambiguity, enhanced communications skills and self-confidence, and improvements in team building and interpersonal interactions. Nevertheless, the integration of practical engineering design into engineering curricula has a long way to go. Todd<sup>10</sup> has addressed issues inherent with engaging, evaluating, and rewarding faculty. Dym and colleagues<sup>11</sup> have detailed challenges associated with teaching design and have provided suggestions for improving design learning, with particular attention to project-based learning. To guide program developers, these authors have defined critical skills associated with design thinking: tolerance for ambiguity, systems thinking and systems design, ability to handle uncertainty, decision making, thinking as part of a team, and thinking and communicating in

several “languages” of design. Fry<sup>12</sup> has also discussed the importance of “design thinking” in engineering education and underscores the value of multidisciplinary teams. Until design practices are fully integrated into engineering curricula, capstone design programs will bear a substantial burden to better prepare undergraduates for careers that inevitably emphasize the “practice” of design.

At RIT, the infusion of multidisciplinary design into the curriculum represents a strategic imperative for the KGCOE. Without strong top-down commitment, the likelihood of making a noticeable impact on the broader challenge outlined above seems remote. In addition to the MSD program discussed in this paper, an undergraduate “honors” program beginning in the freshman year, before students develop technical skills, exposes young students to a wide range of topics and experiences associated with multidisciplinary design, product development, and globalization. A “cornerstone” design course is also available to mid-level undergraduates in Mechanical Engineering, with the expectation of expanding to other departments. RIT’s extensive co-operative education program affords all engineering students more than a year of experience working in industry, which not only contributes to their understanding of real-world design and product development, but also fosters relationships that can lead to MSD projects in their final year at RIT. At the graduate level, Masters programs in several departments offer the opportunity to extend MSD projects into thesis projects, and a graduate level leadership program in Product Development integrates business and systems engineering courses to provide experienced engineers in industry the skills needed to move from senior level engineers to program managers and technically-grounded senior managers. Finally, a new Ph.D. program in Microsystems Engineering has been constructed with strong product realization and systems engineering components. A key strategic intent of the college is to improve linkages between these distinct programs so that students throughout their academic careers are exposed to engineering design concepts and practices critical for success in industry.

The MSD program at RIT arose from departmental capstone design experiences within Mechanical, Industrial, and Electrical Engineering<sup>13</sup>. Since its inception in 2002, the program has grown from a small pilot effort into a college-wide initiative involving four departments and almost 400 students annually. In addition to the three original departments, Computer Engineering joined the program in 2004, although the department continues to offer a discipline-specific capstone course sequence. Students from other colleges at RIT are encouraged to participate in MSD and have done so sporadically (especially from Business and Industrial Design), but broader participation remains a long term goal deserving greater attention.

Components of the current MSD program include a two-quarter course sequence entitled “Multidisciplinary Senior Design (MSD) I&II,” which constitutes the “design-build” core of the program; and a third course entitled “Design Project Management (DPM),” which trains selected students for project management roles in MSD I&II and facilitates early-stage planning and development of a project readiness package (PRP) for each project. The DPM course has been instrumental in reducing the startup time for design teams, but further discussion of redesign efforts in this paper will be limited to the MSD I&II courses. Below is a more detailed description of the courses.

Course description: MSD I&II is two-quarter design course oriented to the solution of real-world engineering problems. The mission is to enhance engineering education through a capstone design experience that integrates engineering theory, principles, and processes within a collaborative environment. Working in multidisciplinary teams and following the product development process, students will develop customer needs and engineering specifications, evaluate concepts, resolve major technical hurdles, and employ rigorous engineering principles to design an alpha prototype which is fully tested and documented. MSD I is focused on planning and designing, while MSD II is dedicated to realizing and testing a prototype of the design. Detailed course and learning objectives and phases are provided later.

Subtle adjustments to the MSD program have been made each year since its inception in 2002, but a major redesign effort was undertaken prior to the 2006 academic year to improve program alignment with departmental objectives, to improve delivery efficiency and effectiveness, and to improve student and faculty satisfaction. A working group consisting of department heads and key faculty spent the summer of 2006 reexamining strategic objectives, identifying critical issues, formulating solutions, and developing an integrated plan for launching a redesigned program in the 2006-07 academic year. Sub-teams focused on project selection, course content, and course delivery and logistics. The project definition process was overhauled to focus on the definition of related projects within a set of disciplinary “tracks,” consistent with academic programs and faculty interests. Emphasis was placed on development of reusable and scalable platforms to lay the foundation for future project refinement and extensions, and to encourage cross-project and cross-department collaboration. To reduce startup time normally associated with student projects, day-long workshops were developed for the first four weeks that forced intense focus on customer requirements, engineering specifications, and concept development and selection. The workshop structure and format further encouraged collaboration within and across teams. Lastly, a Wiki-based online environment was created to support knowledge capture and emergent collaboration. This website is named the Engineering Design Guide and Environment (EDGE), and will be explained in detail later. This paper provides an overview of changes to the MSD program in the key areas of course delivery, project definition, and communications infrastructure. Attention is given to innovative approaches to challenges inherent in serving a large and diverse constituency with limited resources. Companion papers offer more detail on project definition<sup>14</sup> and course delivery and assessment<sup>15</sup>.

## **Project Definition Process Changes**

### **A. Issues Addressed**

In the recent past, projects were proposed primarily by industrial sponsors. These were usually topics that were of interest to them, but not ones that the sponsor thought were on the critical path to develop a new product. Often, they were ones that the sponsor felt were “on the back burner” due to lack of personnel or resources that were currently being utilized elsewhere within the company. Sponsors were asked to provide a project proposal form listing the project scope, deliverables, resources available to the team, and engineering skills needed to successfully complete the project. Despite considerable time and effort spent by the MSD director in the summer months to develop an adequate selection of projects for the fall start-up, summer is vacation time and sponsors very often waited until the start of the fall quarter. This resulted in a scramble to get the necessary documentation in place before the fall start-up. Faculty members

engaged in research activities were also able to propose projects to advance their research efforts. Graduate students were able to work at a high level with an MSD team to leverage their thesis efforts. It was sometimes a challenge to get the attention of faculty members and grad students in the summer months, as well. Once project proposals were submitted, the faculty coordinator team reviewed them for feasibility and modifications were made to fit the sponsor's requirements and the college's educational objectives. This required meetings by the coordinator team throughout the summer months. A change in process was needed to give the MSD Team more control of the project definition process and to spread the effort more evenly throughout the academic year.

In past years, students were not confirmed on a project until the end of the second week of the quarter. The two-week period began with a two-hour poster session to introduce available projects. On the first day of MSD class, team leaders from the DPM course gave a brief project overview of their project, followed by a second poster session. Students were then asked to register their three top choices via a web-based survey form. This information, plus input received by faculty on the skills mix needed for the projects, were then used to assign students to teams. It was an intense and time-consuming two-week process. This took two weeks of productive student work out of the 10-week quarter, forced teams to rush their efforts at the end of the quarter, and was not acceptable.

Now with project tracks, assignments are supplemented by the registration process. Each track is assigned a separate class number, so registering for that class is essentially bidding on the track it represents. This allows a committee to place the students in individual projects within the track (when possible) prior to the start of classes. When MSD meets for the first time, students already know what team they are on, and have read and understood the PRP posted on EDGE. This has virtually eliminated the two-week start up time that was required in the past.

## B. Tracks

Project tracks, give the faculty more control in developing new projects, versus the past solicitation approach. It is more of a "farming approach" rather than the past "hunting approach" that left more to chance. A track is a general category of projects to which a student project may belong. Tracks are helpful for students seeking project membership in that they provide a way to look for a project in an area, but without knowing the specific projects. This eases the registration period for students. Tracks of projects are generally correlated with the various concentrations and options offered through the departments in the KGCOE at RIT. Current tracks are listed below:

### *Assistive Devices and Bioengineering Track*

These projects should generally be of interest to students enrolled in the bioengineering or biomedical options within their departments, or having an interest in applying engineering upon the foundation of the biological sciences. Students in the following programs will likely be interested in this project track: Mechanical Engineering, Mechanical Engineering / Bioengineering Option, Electrical Engineering / Biomedical Option.

### *Aerospace Systems and Technologies Track*

These projects should be of interest to students in the Aerospace Option, or with an interest in Aeronautical systems, aircraft design, spacecraft design, launch and recovery vehicles, and space exploration. Air and Space craft may have a lot of overlap with other vehicle systems, but also have unique aspects related to flight. Students in the following programs will likely be interested in this project track: Electrical Engineering, Mechanical Engineering, Mechanical Engineering / Aerospace Option.

### *Vehicle Systems Technology Track*

These projects should be of interest to students in the Automotive Option, or with an interest in land and sea vehicles. This track includes project to water craft, under-water craft, trucks, cars, trains, inter-modal transportation and logistics, materials handling, forklifts, etc. Also included here are things like IC engines, Fuel Cells, dynamometry, suspension systems, etc. Students in the following programs will likely be interested in this project track: Mechanical Engineering, Mechanical Engineering / Automotive Option, Electrical Engineering.

### *Systems and Controls Technology Track*

These cross-cutting projects deal with the hardware and software of systems, modeling, controls, sensors, actuators, algorithms, etc. Students working in this track may also have an interest in one of the other applications oriented tracks. The Systems and Controls Track generally include projects which are intended to have applications across the other tracks. Students in the following programs will likely be interested in this project track: Computer Engineering, Electrical Engineering, Mechanical Engineering.

### *Sustainable Design and Product Development Track*

These projects will generally be of interest to students in the Energy and Environment Option in Mechanical Engineering, students in the Sustainable Design Minor, or taking the public policy minor from the College of Liberal Arts, etc. Projects include small and large scale energy production and utilization systems including alternate energy systems, projects for third world application, and projects which are focused on product stewardship issues such as recycling, re-use, and re-manufacturing. Students in the following programs will likely be interested in this project track: Electrical Engineering, Industrial and Systems Engineering, Mechanical Engineering, Mechanical Engineering / Energy & the Environment Option, Minor in Sustainable Design.

### *Printing and Imaging Systems Technologies Track*

These projects should be of interest to students doing a minor in Imaging Science, or with an interest in imaging and printing systems. This track consists of projects that involve the development of printer or imaging systems or subsystems, hardware that supports the development of printer and imaging systems, or projects that support hardware development for use in imaging and color science. Students in the following programs will likely be interested in this project track: Electrical Engineering, Mechanical Engineering, Mechanical Engineering / Aerospace Option, Industrial and Systems Engineering, Electrical Engineering, Imaging Science, Minor in Imaging Science.

## C. Families

A "family" is a group of closely related projects, which are all focused on a particular application. Project families are typically built around areas of common interest held by one or more faculty members in the college, regardless of what discipline or technical background they may be from. Often, a family of projects is closely aligned with a particular technology track. Within each project family, the faculty are offering several inter-related projects.

As of the Fall Quarter, 2006-1, the faculty of the KGCOE have defined four project families. At the moment, these project families have a close affinity to the "technology tracks," but also exhibit some overlap across tracks. The current families are listed below:

*Assistive Devices Project Family* - Sponsored by the National Science Foundation. The Assistive Devices and Bioengineering Track is focused on the application of technology to improve the quality of life for individuals with disabilities, and the development of technologies related to the broad field of bioengineering.

*Microsystems Engineering and Technology for the Exploration of Outer Space Regions (METEOR) Project Family* - Sponsored by Harris Corporation. METEOR is the first, university-based project in the world whose ultimate goal is to launch and place small payloads on or near earth asteroids and lunar surfaces. METEOR is a hands-on, multi-phase, multi-disciplinary, teaching, and research program for investigating and developing micro-systems engineering, science, and technologies for the exploration and utilization of outer space. The central focus of the project is the launching of a series of small payloads into low earth orbit, the low earth orbit re-launch and control of these payloads toward the moon or near earth asteroids, the landing of these payloads on the surfaces and the data acquisition and remote control of these payloads during the scientific research phase of each mission. This project will provide the students and faculty at RIT, and the scientific community at large, the opportunity to obtain small payload volumes for conducting micro-systems and other scientific experiments in outer space. METEOR will accommodate and promote these multi-disciplinary collaborations.

*Modular Scalable Robotic Vehicle Platform Family* - Sponsored by the Gleason Foundation. The mission of this family of projects, within the Vehicle Systems Technology Track, is to develop a land-based, scalable, modular open architecture, open source, fully instrumented robotic/remote controlled vehicular platform for use in a variety of education, research & development, and outreach applications within and beyond the RIT KGCOE. The family of projects should use an engineering design process to develop modules and subsystems that can be integrated by subsequent MSD teams. The mission of each student team contributing to this project family is to develop or enhance a particular subsystem for a robotic vehicular platform, and provide complete documentation of the analysis, design, manufacturing, fabrication, test, and evaluation of each subsystem to a level of detail that a subsequent team can build upon their work with no more than one week of background research. This roadmap was initiated during the Fall Quarter, 2006-1, and currently contains seven closely related projects. Additionally, these projects have significant overlap with projects in the Vehicle Systems Technology Track, Aerospace Systems and Technology Track, and the Systems and Controls Track.

*Modular Scalable Systems and Controls Family* - Sponsored by Harris Corporation. Projects within this family are focused on reliable, modular, and scalable solutions that are open

architecture. The goal is to develop open source platforms that are reusable and reliable. The users of these modules may be future RIT MSD projects, RIT research, robotic clubs, radio clubs and other universities who may have an interest. That is, all hardware and software files will be public on the EDGE website this year. Examples are, but not limited to, microcontroller and PC embedded systems, network systems (i.e. CAN, Ethernet, I2C), wireless modules (i.e. RF, IR), alternating current and direct current motor controllers and drivers, analog-to-digital converters/digital-to-analog converters, etc. Though each project in this track has a specific application or use, the project is universal or modular for reusability.

#### D. Project Definition Process

Although the project definition process is currently being defined, the current proposed process is given below.

Project acceptance criteria:

1. *Committed sponsor*: individual (from sponsoring organization) who is most interested in project success and who is responsible for providing financial support.
2. *Fully funded*: all materials, software, and services needed by project team.
3. *Fits into a defined track*: MSD Leadership team may define a new track if the project is determined to be of strategic value.
4. *Must not prohibit students from meeting academic requirements*: information dissemination should not be restricted by the sponsor, intellectual property belongs to the students, timing must agree with course schedule, etc.
5. *RIT champion identified*: faculty, student, or staff member interested and willing to provide internal support (e.g. completed PRP). The RIT champion may be a DPM student, the project sponsor, an associate or liaison to the industrial sponsor, or the track Guide.
6. *PRP approved by MSD Leadership Team*:
  - Resources available (students, Guide) and matched to project scope.
  - High confidence in a positive experience for students.
  - Approval process completed on schedule

Additional considerations:

- Likelihood of generating future projects (e.g. platform or part of portfolio)
- Freedom from confidentiality constraints and intellectual property constraints
- Related to faculty research interests and/or educational thrusts

Project review process:

1. PRP draft prepared: by sponsor, DPM student, or faculty/staff member
2. Draft submitted to DPM instructor or MSD Leadership Team member (or Director) for initial review against selected acceptance criteria (1-4). Possible outcomes are (a) rejection, (b) postponement, or (c) identification of RIT champion to complete PRP.
3. PRP updated by RIT champion and submitted to project Guide (assigned by MSD Leadership Team). [*We may have a standing sub-team to review PRP's, particularly if the submission date is well in advance of implementation date.*]
4. PRP reviewed by project Guide. The Guide is responsible for securing reviewers from other departments and gaining approval from those reviews. The Guide is also responsible for any final changes needed before releasing the PRP to students.

5. Guide submits recommendation to MSD Leadership Team for final disposition: “accept”, “reject”, or “postpone”.

#### E. Student Assignments

In the fall 20061, students bid on a track through the EDGE website, by selecting one or more tracks that they were interested and willing to work on. If they were interested in working on a specific project within a track, and if they preferred to work with friends or other specific classmates, they also indicated that as well. Matching students with their preferences and reconciling that with preference input received from faculty, was a time consuming challenge, given the large number of students, and the mix of information received from them. In winter 20062, the task was made considerably easier by assigning section numbers to the tracks and having students register for the section corresponding to the track of interest. Pre-wired faculty preferences and resolving issues with more or less students selecting a project than was allotted, still needed addressing, but this was accomplished in one two-hour faculty meeting before the start of winter classes, a great improvement over the fall quarter. Students were made aware that their preferences would be accommodated whenever possible, but that they might be assigned to another project within the track, or possibly to another track all together.

#### F. Faculty Roles and Responsibilities

In the new MSD system, faculty members act as either “guides” or “consultants.” A guide is a faculty member who is the primary mentor for the project. He or she is the most intimately involved with the entire process, and remain with the team for both quarters of MSD. The guide is also ideally an expert in the field of the project’s subject matter. He or she meets with their team weekly, helps resolve technical issues, provides advice on resolving personnel conflicts, and grades the team on its deliverables. The final individual student grade is also adjusted up or down by the guide. After reviewing the logbooks, peer evaluations, and looking at the overall participation, the grade can be modified to reflect the student’s overall contribution.

The guide most often acts as the administrative point of contact. He or she will handle any logistical issues, help with ordering parts, make changes in the schedule, etc. Furthermore, he or she is responsible for approving purchases and for keeping total expenditures within budget. Before the team is ever official created, the guide is usually the most instrumental person in creating, revising, and/or approving the PRP. He or she is also instrumental in providing the team with guidance during the all-day workshops at the beginning of the MSD course.

Technical issues beyond the expertise of the guide can be referred to a consultant. There are often multiple consultants for each team, and can consist of other faculty members, teaching assistants, or people in industry. The consultants will usually have expertise or important knowledge in specific areas of the project. They will ideally compliment the guide, many times in other academic disciplines. Finally, the consultants will often give the guide input on grading the team.

### **Course Delivery Process Changes**

#### A. Development Process

MSD I course objective: Following the product development process, develop customer needs and engineering specifications, evaluate concepts, resolve major technical hurdles, and employ rigorous engineering principles to design an alpha prototype. Develop a design verification plan and fully document design. Phases and timeline:

1. Planning: Project plan and schedule including specific deliverables and due dates (weeks 1-3).
2. Concept Development
  - a. Detailed, quantitative target specifications mapped to customer needs (weeks 1-3).
  - b. Develop multiple concepts (on paper) and select the most feasible; update specifications, integrate customer feedback (week 4).
3. System-Level Design:
  - a. System design including architecture, sub-system definition, interface definition, and more detailed specifications. Appropriate engineering analysis including hand calculations and simulation / modeling. Determine greatest challenges / risks to project. Concept review (week 5).
  - b. Proof of concept breadboard, brassboard, or simulation of high risk technologies defined in 3a. Use appropriate discipline specific methods to demonstrate confidence in selected architecture and design approach. Risk assessment for technology, cost, and schedule (weeks 6-7).
4. Detail Design:
  - a. Detailed design to meet all customer needs. All long lead items should be identified for ordering. Technical design review (weeks 8-9).
  - b. Detailed test plan with linkage to engineering specifications and customer needs. The results of this plan should demonstrate the design meets all customer needs and translated engineering specifications (both high level specifications and cascaded sub-system specifications; week 10).
  - c. Project plan for SDII (week 10).
  - d. Project review (week 10).

MSD II course objective: Following the product development process, build an alpha prototype and demonstrate performance meets specifications. Fully document alpha design and verification testing. Phases and timeline:

1. Detail Design: Finalize full system design; design review (weeks 1-2).
2. Testing and Refinement:
  - a. Full feature / function alpha prototype (weeks 3-6).
  - b. Design Verification testing; execution of detailed test plan with results documented; Design Review and prototype demonstration (weeks 7-8).
  - c. Design History File completion (EDGE web site). Generation of conference paper and poster that cover customer needs, specifications, highlights of design, results of design verification testing, and future work (week 9).
  - d. Project review (week 10).

## B. Course Deliverables and Grading

There are a series of both major and minor graded deliverables in the MSD I & II sequence, as outlined in Tables 1 and 2. These deliverables have been modified from past offerings of MSD I & II based on student and faculty feedback. Primary goals were to give students feedback earlier

in the quarter and give students a more aggressive timeline so that they are more likely to be able to build and test their designs and include actual prototype results in end-of-quarter presentations and papers.

In keeping with the effort to encourage students to jump right into the project and in response to anecdotal student feedback that they would like feedback earlier in the quarter, there are process-related deliverables due each week early in MSD I, culminating in a major Concept Review during week 5. For the remaining part of the quarter, students work relatively independently on their design and analysis. Teams complete a Detailed Design Review during Week 9, where faculty and industry representatives critically evaluate their design in detail, and a high-level Project Review during week 10. By the end of the quarter, teams are also required to submit a preliminary Test Plan document and preliminary MSD II schedule in preparation for the second quarter of the 2-course sequence.

MSD II deliverables are aimed at enabling students to end the quarter with a working prototype, and a technical paper and poster describing the results of their design. A final Detailed Design Review requires students to have finalized project details, including all drawings, sources for purchased materials, and final budget and Bill of Materials. This gives students 5-6 weeks to construct and test their designs before being graded on a prototype, and an additional 1-2 weeks to compile results into a technical paper and poster.

Table 1. Graded deliverables for MSD I (10 Week Quarter)

Deliverable	Due	Weight	Comment
Customer Needs	Week 2	3%	Nearly 40% of grade determined by mid-quarter – students are receiving early feedback
Design Specifications	Week 3	3%	
Complete MSD I Schedule	Week 3	3%	
Concept Review	Week 5	30%	
Detailed Design Review	Week 9	30%	
End-of-Quarter Project Review	Week 10	10%	
Preliminary Test Plan	Week 10/11	3%	
MSD II Schedule	Week 10/11	3%	
Class and Within-Team Participation	Week 11	15%	
Final MSD I Grade		100%	

Table 2. Graded deliverables for MSD II (10 Week Quarter)

Deliverable	Due	Weight	Comment
Detailed Design Review II	Week 2	15%	Earlier prototype testing means results can be included in poster and technical paper
Function and Performance Review	Week 7/8	20%	
Poster	Week 9	10%	
Technical Paper	Week 9	15%	
Website/Design History File	Week 10	15%	
Final Project Review	Week 10	10%	
Class and Within-Team Participation	Week 11	15%	

Final MSD II Grade		100%	
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Grading for each of the deliverables in Tables 1 and 2 are based on detailed, objective grading rubrics. There is a precedent for using this method to grade MSD projects<sup>16</sup> and by providing instructors and team Guides with a standard rubric, more uniform grading across all teams should result. These grades are assigned for teams as a whole, and not for individual students. However, there are fairly detailed grading guidelines for individual students based on class and within-team participation. Attendance and participation in class and team meetings are tracked, as is student use of either their Design Notebook or their record of files on the team's project website. This grade contributes 15% of the student's total grade each quarter. Additionally, students are given an opportunity to submit peer evaluations at the end of the quarter to indicate whether certain team members participated above or below the team average for each major graded deliverable. This allows team Guides to modify a student's grade for individual deliverables, giving more flexibility in grade assignment in the extreme cases where one student contributes far above or below the team average and earns differentiation of more than one letter grade.

### C. Workshops and Seminars

A series of just-in-time workshops, seminars, and tutorials are incorporated within MSD I and II as shown in Tables 3 and 4. To reduce startup time normally associated with beginning the design process, four day-long workshops were incorporated within MSD I during the fall of 2006. Each workshop included a one to two hour interactive classroom experience where various key design phases were the focus. During each of these workshops, teams were presented with necessary design related information, they were asked to practice the design methodology on their projects, and given fifteen to twenty minutes to explore together. Attendance at workshops is strongly encouraged and topics include customer requirements, engineering specifications, concept generation, and concept selection. Other course activities which were added throughout MSD I and II were optional and briefer in nature.

Table 3. Multi-Disciplinary Senior Design I

Week No.	Course Activities
1	<i>Workshop:</i> Course Introduction and Project Kickoff
2	<i>Workshop:</i> Translating Needs to Specifications <i>Tutorial:</i> EDGE website
3	<i>Workshop:</i> Functional Decomposition and Concept Generation
4	<i>Workshop:</i> Concept Generation and Selection <i>Seminar:</i> Preparation for Concept Reviews <i>Tutorial:</i> Advanced EDGE & Wiki <i>Seminar:</i> Drive Circuits for Output Devices
5	<i>Entrepreneurship Conference:</i> <a href="http://entconf.cob.rit.edu/">http://entconf.cob.rit.edu/</a>
6	<i>Seminar:</i> Noise Immunity Techniques <i>Seminar:</i> Embedded Linux and Software Development <i>Seminar:</i> Preparation for Design Reviews
7	<i>Seminar:</i> How to prepare a drawing package? <i>Seminar:</i> Analog to Digital Conversion
8	<i>Seminar:</i> Preparation for Project Reviews

	<i>Seminar:</i> Harnesses, connectors, test points, LEDs <i>Seminar:</i> PCB Layout application and Surface Mount Tour <i>Seminar:</i> Fatigue analysis <i>Seminar:</i> Linux overview
11	<i>Focus Groups:</i> Informal Feedback Opportunity

Table 4. Multi-Disciplinary Senior Design II

Week No.	Course Activities
1	<i>Workshop:</i> Course Overview
3	<i>Seminar:</i> Technical Paper Requirements
4	<i>Seminar:</i> What should be included on the project poster?
6	<i>Seminar:</i> Oral Presentation Skills
8	<i>Seminar:</i> Preparation for Final Project Review
11	<i>Focus Groups:</i> Informal Feedback Opportunity

## Communications Infrastructure Changes

### A. Online Environment

To support the knowledge capture and emergent collaboration of the MSD system, a Wiki-based online environment was created, titled EDGE. EDGE is an open source integrated design environment, which fosters collaboration within design project teams and across design teams. This site provides students, faculty, staff, and sponsors with tools and information to help them be successful in their design projects, and to learn about modern design and product development processes. The EDGE web site and design environment is intended to grow over time both in level of content and in sophistication<sup>17</sup>.

The new version of EDGE uses a format called Wiki. In general terms "wiki" is a Hawaiian word meaning "quick". A Wiki is a website that allows the visitors themselves to easily add, remove, and otherwise edit and change available content. This ease of interaction and operation makes a Wiki an effective tool for mass collaborative authoring<sup>18</sup>. The text-based structured markup, used by Wiki pages, facilitates rapid creation of informational pages and distributed development of content.

All information on the EDGE website is organized by projects. Each project has its own physical web page. Super-projects comprise the highest level of this organization, and typically provide infra-structure for the site. Each course (e.g. MSD1) or common utility (e.g. Resources) has its own super-project. Information can easily be disseminated to the students using super-projects, including schedules, grading, assignments, etc.

The super-projects are further broken down to other pages, called tracks. A track is a general category of projects (e.g. Vehicle Systems Technology Track). Tracks of projects are generally correlated with the various concentrations and options offered throughout the departments in the KGCE at RIT.

Lower level web pages can also be created. These individual pages are called nodes. Each student project is a single node, and may also contain an indiscriminant number of other nodes –

shown as links. Development of pages in this format is a natural process of explaining information. Generally, each page contains a single topic. Because of the ease of page creation and linking, if one page discusses a related topic, a link can be created to that topic to allow the reader to quickly refer to other material.

For file management, EDGE uses “subversion” – a modern Version Control system, used for centralized data storage and distributed editing. Using subversion to manage project materials allows the project members to be bold about making changes to the project's design files. This is mainly because<sup>17</sup>:

- No information that enters a repository ever leaves, it just becomes out-of-date
- It allows members to track the status of a project against their own development
- It gives a safety net to the project member's efforts
- All material in files (especially text files) is traceable to a single author and commit time

Because versioning occurs at the repository level, a particular revision is a snapshot in time of all the files in the repository. This makes it easy to find problems that occur because of interrelationships between files. If something breaks it can be back-tracked until it works again and the differences between the two versions can be examined to give insight into the problem<sup>17</sup>.

There are many advantages to using the aforementioned system of organization found in EDGE. First, the website, and therefore project information and files, can be accessed from any computer with internet access. Anyone granted proper viewing/editing rights can review and edit information in real time. This facilitates organization, aides in the development of a design history file, helps prevent redundant work between group members, and greatly assists in working and reviewing outside of the class room. Because any editor of a project can write a Wiki page, this method allows information to stay as up-to-date as possible.

## B. Collaboration

Throughout the entire history of MSD, communication barriers have been present when working with students of varying disciplines. However, due to the new structure of MSD, other communication and collaboration issues have arisen. While the interaction between individual members within teams has remained largely the same, whole teams are pushed to work together more than ever before. Projects often share a budget, goals, and many different resources. This collaboration occurs not only between current projects, but is also effected by the decisions of previous teams.

Although collaboration is not a unique problem for one team, it may be best to look at an individual example for clarification. The Modular Scalable Robotic Vehicle Platform Family will be examined more closely.

Many of the tracks within the MSD program have separate projects that share a common overall goal. The Modular Scalable Robotic Vehicle Platform Family has numerous projects dealing with individual aspects of producing new modular and scalable robotic platform. While meeting individual team goals, they need to always keep in mind the overall customer needs.

Collaboration between all teams – past, present, and future – is imperative to the success of the track as a whole. If the team designing the “motor modules” (to move the robot) do not collaborate with the team designing the platform (to power the robot), the overall robot design will fail. Even beyond the robot itself, if the team designing the dynamometer (to test the efficiency of the entire robot chassis) does not collaborate with all of the teams designing the robot, it may not be useful. All of these teams must be technically compatible.

The overlap is not always kept within tracks. Collaboration between projects within multiple tracks is often necessary. For example, teams within the System and Controls Technology Track were given the task to design and build a motor controller and data acquisition system for use on the robotic platform. If the physical connections, program commands, or communication protocol are not standardized between all the teams linked to the robotic platform, regardless of what track they are in, the overall goal will never be realized.

To further complicate the relationship between these teams, they must share a single budget provided by the customer. In the past, each MSD team was given an individual budget to work from. In the new system, many teams are forced to look at their needs in conjunction with those of the entire family. They have had to consider trade-offs and often select a lower cost alternative, to ensure that the total expenditure for all cooperating projects stay below the total provided by the customer. Each team, after designing their individual system, must convince the guide and/or the customer that their self-determined budget is reasonable and responsible.

As a result of these new challenges, teams have had to communicate and coordinate activities at a level seldom required in the past. Guides have encouraged teams to work together and share ideas and resources freely and openly. An emphasis has been placed on only completing each task once (i.e. not “reinventing the wheel”). Instead of two teams designing a separate printed circuit board to power the robot, one can be designed together using collaboration. Because this reduces the amount of work done by each team, requirements can be increase, and more can be accomplished in a shorter time.

Students have been given the freedom to determine their own methods for collaboration and communication. Numerous meetings have been held with representatives from all teams involved. While Electrical and Computer Engineers discuss communication protocol and connection points in one room, Mechanical and Systems Engineers discuss wheel selection and motor mounting points in another. Email and the EDGE website are also very important tools for the meshing and integration of designs.

Because of these interdependencies, teams are frequently required to show that they can accommodate the systems being developed by others. However, should these other teams not deliver their subsystem on schedule, it is necessary to have a back-up plan that provides similar functionality. It is a difficult process for many teams to get past the lack of control they feel, as a result of these interdependencies. If teams heavily rely on another team’s final product, issues with budget and time constraints arise when trying to plan for the worst case scenarios. It must be understood that the demonstration is still a key factor in the final grade, whether another team completes their project or not.

The standardization of documentation is also an ever increasing problem between teams. If a different Computer Aided Drafting program is used by one team, their drawings may not be easily used for the design requirements of others. The organization of all forms of documentation can have a significant impact of the success of projects requiring collaboration. The easier it is for teams to assimilate work done by other teams, the better the outcome of the final product.

### Assessment of Redesign Effort

#### A. Students

Assessment of the MSD I & II sequence has been aimed at student satisfaction with the course structure, class presentation, and introduction of the new workshop format and track system implemented in the Fall 2006. Key findings to date are outlined in Table 5, and specific information regarding implementation of the workshop format can be found in a separate paper<sup>15</sup>. Surveys indicate that students are more satisfied with the new workshop format than the original lecture format, and that the switch to the new format did not affect their perceived level of learning. While no formal faculty feedback has been collected, informal feedback indicates that faculty are pleased with the course improvements and the structure of the new grading rubric.

Table 5. Student feedback on old and new course formats

Criteria	Old Format	New Format
% of students rating structured class time (i.e., lecture or workshop) as “good” or “very good”	14.5%	36%
% of students rating structured class time (i.e., lecture or workshop) as “poor” or “very poor”	52%	50%
% of students rating new workshop format as “good” or “very good” if students are immediately given an opportunity to apply lecture material to their projects	N/A	63%
% of students indicating that track system was <i>beneficial</i>	N/A	50%
% of students indicating that track system was <i>a hindrance</i>	N/A	18%
Average student self-assessment of <i>increase in ability to meet course objectives</i> after taking MSD course	11%	12%

#### B. Learning Objectives

Major topics were discussed between academic years, leading to changes in many of the MSD objectives. A major student issue with the past system was the emphasis on process and not enough focus on engineering rigor. More importance has been placed on balancing engineering rigor, overall analysis, team size, and previous work experiences with documentation and process requirements. The updated MSD learning objectives are listed below:

1. Ability to explain the product development process in the context of the product life cycle.
2. Ability to perform a critical analysis of requirements, engineering specifications, and the relationship between them.

3. Ability to integrate theory from a broad range of courses, laboratory exercises and co-op experiences to the solution of an engineering design problem.
4. Ability to employ a rigorous design process that includes ideation, analysis, synthesis, implementation, and test against engineering specifications.
5. Ability to document product development activities.
6. Ability to effectively communicate technical, discipline specific information through oral and written means.
7. Ability to work effectively in a multidisciplinary team environment, to communicate and make tradeoffs, within and across disciplines, to meet project requirements.
8. Ability to explain the impact of project schedule, critical paths, and budgetary constraints on the effective execution of an engineering design.
9. Ability to be perform a self-assessment of skills, aptitudes, and preferences against project roles and responsibilities.
10. Ability to assess the societal impact of design choices and to make ethical engineering design decisions.

### **Future Plans**

As has been the case in the past, assigning a range of individual grades within a team based on differing logbook content and peer evaluation input continues to cause resentment for those who receive lower grades as compared to uniform grades within a team. Students receiving lower grades are somewhat surprised when this happens. A corrective action planned for this quarter is to have a peer evaluation after each team deliverable, to address those individuals that are not apparently pulling their weight. Logbooks, however, are not typically critically assessed until the end of the quarter when a holistic appraisal of the individual's entire quarters work can be compared against his/hers team member's logbooks. This may hinder the achievement of the goal to eliminate surprising an individual with a grade below that of his/her team mate.

Although required workshops at the start of MSD I have been more focused on helping teams get started on Needs Assessment, Specifications, and Concept Development and Selection, many continue to resent having to attend a specified number (5) of additional seminars throughout the quarter. This distracts from focus on getting project deliverables completed. This quarter, a corrective action being considered is to eliminate required attendance at additional seminars, and to make them voluntary where attendance will depend on perceived value-add.

What has gone very well is the early assignment of students to teams before the start of classes, and the rapid ramp-up of team efforts to get organized, decide team roles, and get started on completing project deliverables. Students still register for or drop out of the course (when they do not get the project assignment they wanted) at the last minute. However, quick adjustments to the team rosters and sometimes the project scope are made to match the last minute changes in course registration.

The lack of faculty participation at design reviews is still a major issue, and more incentives from department heads are needed to convince some that their participation is valued and counted in their work-load model and appraisal. Participation by industrial representatives at design reviews continues to be sought and appreciated when it occurs, but this does not always

happen as many of these individuals are working more hours and doing more with fewer resources, so this is still a problem in search of a solution.

## Conclusions

In conclusion, we have been able to make use of several course features and activities to make the delivery of a large course more efficient for the faculty and effective for the students:

- Streamline project selection process so that the only projects undertaken are those that are well-defined, with faculty and/or students who have a vested interest in the project's success.
- Group together projects with similar requirements and goals so that student teams can work together to solve common problems, rather than relying entirely on faculty and a small team for guidance. This also streamlines the process of assigning students to projects.
- Facilitate communication between teams so that information can be shared more easily.
- Rely on small-group workshops targeted at specific student or team needs to convey information, rather than using a large lecture format that all students must attend regardless of interest/need or time consuming one-on-one help that must be given to many different teams individually.
- Map out deliverables and clear expectations for the students early on so that they know what tasks must be completed, when they are due, and what the content should be.

## Acknowledgments

In addition to the authors, members of the MSD Committee, listed below, participated in the redesign of the program:

- Dr. Vinnie Amuso; Associate Professor and Head of EE
- Dr. Marcos Esterman; Assistant Professor of ISE
- Dr. Edward Hensel, PE; Professor and Head of ME
- Dr. Alan Nye; Professor of ME
- Dr. Daniel Phillips; Associate Professor of EE
- Dr. Pratapa Reddy; Professor of CE

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