W O R C E S T E R   P O L Y T E C H N I C   I N S T I T U T E

PROPOSAL FOR A MAJOR IN ROBOTICS ENGINEERING

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1 INTRODUCTION

Robotics—the combination of sensing, computation and actuation in the real world—is on the verge of rapid growth, driven by both supply and demand. The supply side is driven by decreasing cost and increasing availability of sensors, computing devices, and actuators. The demand side is driven by national needs for defense and security, elder care, automation of household tasks, customized manufacturing, and interactive entertainment. Engineers working in the robotics industry are mostly trained in one of Computer Engineering, Computer Science, Electrical Engineering, Mechanical Engineering, and Software Engineering. No single discipline provides the breadth demanded by robotics in the future.

Worcester Polytechnic Institute, with its emphasis on project-oriented education, flexible curriculum, and intense coursework, is the ideal university to undertake the education of future robotics engineers and scientists. Therefore, we propose to institute the nation's first undergraduate Robotics Engineering degree program at WPI that will educate young engineers for the robotics industry and prepare students for graduate work in robotics, leverage WPI's presence in robotics competitions, contribute to the growth of the local robotics industry, increase undergraduate enrollment and generate additional revenue, attract outstanding faculty, stimulate research in robotics, and position WPI as the leader in educational innovation.

The major represents a joint effort by faculty in the Departments of Computer Science, Electrical & Computer Engineering, and Mechanical Engineering. Although Robotics Engineering is not recognized as a distinct engineering field by ABET, we have planned the program as if it were accreditable. In addition, the program includes an entrepreneurship component to prepare future "enterprising engineers".

Sections 2 and 3 of this proposal comprise the motions presented to the WPI Faculty for approval. Section 2 comprises the Distribution Requirements for the Robotics Engineering major. These requirements are consistent with those of ABET-accredited programs at WPI.

Section 3 describes courses to be added in Robotics Engineering. We propose adopting the prefix RBE for courses in the major.

Sections 4 through the Appendices are not part of the motions. Rather, they provide context for the motions, including rationale, resources, and management. Section 4 provides a detailed rationale for the major.

Section 5 identifies the resources required to effectively implement the major.

Section 6 outlines the management and administration of the major, and discusses the implementation schedule.

Appendices provide supporting material for the proposal.

We are currently seeking endorsement of the proposal from the WPI Departments of Computer Science, Electrical & Computer Engineering, and Mechanical Engineering, and the Administration.

2 DISTRIBUTION REQUIREMENTS

Motion: The Distribution Requirements for the B.S. in Robotics Engineering are:

ROBOTICS ENGINEERING	Minimum Units
1. Mathematics (Note 1)	7/3
2. Basic Science (Note 2)	4/3
3. Entrepreneurship	1/3
4. Engineering Science and Design, including the MQP (Notes 3, 4, 5, 6, 7, 8, 9)	6

Notes:

1. Must include Differential and Integral Calculus, Differential Equations, Linear Algebra, and Probability or Statistics.
2. Must include at least 1 unit in Physics.
3. Must include at least 5/3 units in Robotics.
4. Must include at least 1 unit in Computer Science, including Algorithms and Software Engineering.
5. Must include at least 2/3 units in Electrical and Computer Engineering, including Embedded Systems.
6. Must include at least 1/3 unit in Controls.
7. Must include at least 1/3 unit of Social Implications of Technology (CS 3043, GOV 2302, GOV/ID 2314, IMGD 2000, STS 2208). Any of these courses used to satisfy the 2/3 unit Social Science requirement may not also count toward the 6 units Engineering Science & Design requirement.
8. Must include at least 1 unit from a list of Robotics Electives, of which at least 1/3 unit must be in Advanced Systems (CS 4341, ECE 3308, ME 3310).
9. The MQP must be a Capstone Design Experience in Robotics Engineering.

3 COURSES

3.1 EXISTING COURSES

Motion: Renumber course ES 2201 Introduction to Robotics to RBE 1001, by dropping course ES 2201 Introduction to Robotics and adding course RBE 1001 Introduction to Robotics.

RBE 1001 INTRODUCTION TO ROBOTICS (FORMERLY ES 2201)
Cat. I
Multidisciplinary introduction to robotics, involving concepts from the fields of electrical engineering, mechanical engineering and computer science. Topics covered include sensor performance and integration, electric and pneumatic actuators, power transmission, materials and static force analysis, controls and programmable embedded computer systems, system integration and robotic applications. Laboratory sessions consist of hands-on exercises and team projects where students design and build mobile robots.
Undergraduate credit may not be earned for both this course and for ES 2201.

Recommended background: mechanics (PH 1110/ PH 1111). Suggested background: electricity and magnetism (PH 1120/ PH 1121), may be taken concurrently.

Motion: Cross-list course ME 4322 Modeling and Analysis of Mechatronic Systems as RBE/ME 4322 and ME 4815 Industrial Robotics as RBE/ ME 4815.

RBE/ME 4322 MODELING AND ANALYSIS OF MECHATRONIC SYSTEMS
Cat. I
This course introduces students to the modeling and analysis of mechatronic systems. Creation of dynamic models and analysis of model response using the bond graph modeling language are emphasized. Lecture topics include energy storage and dissipation elements, transducers, transformers, formulation of equations for dynamic systems, time response of linear systems, and system control through open and closed feedback loops. Computers are used extensively for system modeling, analysis, and control. Hands-on projects will include the reverse engineering and modeling of various physical systems. Physical models may sometimes also be built and tested.
Recommended background: mathematics (MA 2051, MA 2071), fluids (ES 3004), thermodynamics (ES 3001), mechanics (ES 2501, ES 2503)

RBE/ME 4815 INDUSTRIAL ROBOTICS.
Cat. I
This course introduces students to robotics within manufacturing systems. Topics include: classification of robots, robot kinematics, motion generation and transmission, end effectors, motion accuracy, sensors, robot control and automation. This course is a combination of lecture, laboratory and project work, and utilizes industrial robots. Through the laboratory work, students will become familiar with robotic programming (using a robotic programming language VAL II) and the robotic teaching mode. The experimental component of the laboratory exercise measures the motion and positioning capabilities of robots as a function of several robotic variables and levels, and it includes the use of experimental design techniques and analysis of variance. Recommended background: manufacturing (ME 1800), kinematics (ME 3310), control (ES 3011), and computer programming.

Implementation: These changes will take effect Fall 2007 and appear in the 2007-08 Undergraduate Catalog.

Course ES 2201 will be taught twice in AY 2006-07. We plan to offer RBE 1101 in B and D Terms each year, requiring no additional resources beyond those already committed to ES 2201.

Courses ME 4322 Modeling and Analysis of Mechatronic Systems and ME 4815 Industrial Robotics have already been approved by the WPI faculty; cross-listing them requires no additional resources. These courses will continue to be offered at the present frequency of once per year and twice per year, respectively.

3.2 NEW COURSES

Motion: Add courses RBE 2001 Unified Robotics I, RBE 2002 Unified Robotics II, RBE 3001 Unified Robotics III, RBE 3002 Unified Robotics IV, and RBE/ME 3222 Introduction to Mechatronics.

RBE 2001 UNIFIED ROBOTICS I
Cat. I
First of a four-course sequence introducing foundational theory and practice of robotic engineering from the fields of computer science, electrical engineering and mechanical engineering. The focus of this course is the effective conversion of electrical power to mechanical power, and power transmission for purposes of locomotion, and of payload manipulation and delivery. Concepts of energy, power and kinematics will be applied. Concepts from statics such as force, moments and friction will be applied to determine power system requirements and structural requirements. Simple dynamics relating to inertia and the equations of motion of rigid bodies will be considered. Power control and modulation methods will be introduced through software control of existing embedded processors and power electronics. The necessary programming concepts and interaction with simulators and Integrated Development Environments will be introduced.

Laboratory sessions consist of hands-on exercises and team projects where students design and build robots and related sub-systems.

Recommended background: ES 2201/RBE 1001, PH 2201 (can be taken concurrently), ECE 2011 or ECE 3601

This course will be offered starting in 2007-08.

RBE 2002 UNIFIED ROBOTICS II
Cat. I
Second of a four-course sequence introducing foundational theory and practice of robotic engineering from the fields of computer science, electrical engineering and mechanical engineering. The focus of this course is interaction with the environment through sensors, feedback and decision processes. Concepts of stress and strain as related to sensing of force, and principles of operation and interface methods for electronic transducers of strain, light, proximity and angle will be presented. Basic feedback mechanisms for mechanical systems will be implemented via electronic circuits and software mechanisms. The necessary software concepts will be introduced for modular design and implementation of decision algorithms and finite state machines.

Laboratory sessions consist of hands-on exercises and team projects where students design and build robots and related sub-systems.

Recommended background: RBE 2001, CS 1101 or CS 1102

This course will be offered starting in 2007-08.

RBE 3001 UNIFIED ROBOTICS IIII
Cat. I
Third of a four-course sequence introducing foundational theory and practice of robotic engineering from the fields of computer science, electrical engineering and mechanical engineering. The focus of this course is actuator design, embedded computing and complex response processes. Concepts of dynamic response as relates to vibration and motion planning will be presented. The principles of operation and interface methods various actuators will be discussed, including pneumatic, magnetic, piezoelectric, linear, stepper, etc. Complex feedback mechanisms will be implemented using software executing in an embedded system. The necessary concepts for real-time processor programming, re-entrant code and interrupt signaling will be introduced.

Laboratory sessions will culminate in the construction of a multi-module robotic system that exemplifies methods introduced during this course.

Recommended background: RBE 2002, ECE 2801, CS 2223, MA 2051

This course will be offered starting in 2008-09.

RBE 3002 UNIFIED ROBOTICS IV
Cat. I
Fourth of a four-course sequence introducing foundational theory and practice of robotic engineering from the fields of computer science, electrical engineering and mechanical engineering. The focus of this course is navigation, position estimation and communications. Concepts of dead reckoning, landmark updates, inertial sensors, vision and radio location will be explored. Control systems as applied to navigation will be presented. Communication, remote control and remote sensing for mobile robots and tele-robotic systems will be introduced. Wireless communications including wireless networks and typical local and wide area networking protocols will be discussed. Considerations will be discussed regarding operation in difficult environments such as underwater, aerospace, hazardous, etc.

Laboratory sessions will be directed towards the solution of an open-ended problem over the course of the entire term.

Recommended background: RBE 3001. Suggested background: ES 3011

This course will be offered starting in 2008-09.

Implementation: The Unified Robotics courses will be offered starting with RBE 2001 and 2002 in C and D Terms 2008, respectively. Commencing with the 2008-09 academic year, the Unified Robotics sequence RBE 2001–3002 will be offered with RBE 2001 in A Term through RBE 3002 in D Term each year. These courses will be listed in the 2007-08 Undergraduate Catalog. These courses will require additional faculty and laboratory resources, which have been requested.

4 RATIONALE

4.1 OVERVIEW

> *We think robotics is poised to take off rapidly, and there are solid indications that this is true! With component hardware costs coming down and computational capabilities increasing, the robotics industry appears to have the right conditions to really grow quickly.*
>
> Tandy Trower, General Manager, Microsoft Robotics Group[1]

Robotics—the combination of sensing, computation and actuation in the real world—is experiencing rapid growth, driven by both supply and demand. On the supply side, decreasing cost and increasing availability of sensors, computing devices, and actuators translate into practical robotic devices in the marketplace, with more on the horizon. On the demand side, the increasing pull of national needs for defense and security, elder care, automation of household tasks, customized manufacturing, and interactive entertainment will lead to large markets for robotic devices.

Engineers working in the robotics industry are mostly trained in one of Computer Engineering, Computer Science, Electrical Engineering, Mechanical Engineering, and Software Engineering. No single discipline provides the breadth demanded by robotics in the future.

Worcester Polytechnic Institute, with its emphasis on project-oriented education, flexible curriculum, and intense coursework, is the perfect university to undertake the education of future robotics engineers and scientists. Therefore, we propose to institute a Robotics Engineering degree program at WPI. This major will:

- Educate young engineers for the robotics industry and prepare students for graduate work in robotics,
- Leverage WPI's presence in FIRST, BattleCry, and other robotics competitions to capture the imagination of secondary school students and their parents to draw a diverse student body,
- Contribute to the growth of the robotics industry in New England,
- Increase undergraduate enrollment at WPI and generate additional revenue for WPI,
- Attract outstanding faculty,
- Stimulate research in robotics at WPI, and

[1] http://msdn.microsoft.com/robotics/getstarted/intro/default.aspx

- Position WPI as the leader in educational innovation.

4.2 PROGRAM OUTLINE

The major represents a joint effort by the Departments of Computer Science, Electrical & Computer Engineering, and Mechanical Engineering. Some of the faculty and courses required for the major already exist at WPI; others will need to be brought on.

The Robotics Engineering curriculum will draw extensively from the above fields plus mathematics, with additional courses from science and management. In addition, we propose to develop 6 new courses to provide a comprehensive treatment of CS, ECE, and ME as applied to robotics. As the program matures and enrollment increases, we may increase the frequency of course offerings and develop additional courses.

4.2.1 EXISTING COURSES

To provide the necessary breadth in the foundational disciplines, the Robotics Engineering major distribution requirements are constructed to ensure a background including:

- CS to the level of CS 2223 Algorithms and CS 3733 Software Engineering,
- ECE to the level of ECE 2801 Embedded Computing Systems,
- ES/ME to the level of ES 3011 Controls,
- MA to the level of MA 1024 Calculus IV, MA 2051 Differential Equations, MA 2071 Linear Algebra, and Probability or Statistics
- Physics to the level of PH 2201 Intermediate Mechanics I, and
- Entrepreneurship, such as ETR 3910 Recognizing and Evaluating New Venture Opportunities.

The phrases "CS to the level of CS 2223" etc. require elaboration. Following the recommendations in the Undergraduate Catalog, taking CS 2223 and CS 3733 requires 4 CS courses[2]—1 more than the proposed RBE Distribution Requirements—and ECE 2801 requires 3 ECE courses—1 more than the proposed RBE Distribution Requirements. In addition, RBE students should know about Statics and Dynamics, which ME majors typically get in ES 2501 Statics and ES 2503 Dynamics. Including these 4 courses in the curriculum would, unfortunately, exceed 10 units in the major and/or leave no room for robotics elective and/or eliminate Unified Robotics I–IV. Therefore, we decided to remove 4 courses from CS, ECE, and ES, and cover much of that material in Unified Robotics and PH 2201 Intermediate Mechanics, as described below

In addition, to encourage more depth in some area, we require 1 course from the set {CS 4341 Artificial Intelligence, ECE 3308 Wireless Networks, ME 3310 Kinematic Mechanisms}. Because of the desire to include introductory courses from several majors, the program is shaped differently than most majors at WPI. Most majors exhibit a balance between 2000-, 3000- and 4000-level courses.

[2] Treating CS 2022 / MA 2201 Discrete Mathematics as a MA course, 5 when treated as a CS course.

We propose a program that is weighted toward 2000- and 3000-level courses, with no required 4000-level courses, although some 4000-level courses are listed as Robotics Electives. .

4.2.2 NEW COURSES

We propose to teach the following new courses as part of the RBE major:

- RBE 1001 (to be taught in A and B Terms 06 as ES 2201) Introduction to Robotics.
- RBE 2001, 2002, 3001, 3002 Unified Robotics I-IV.

RBE 1001 provides a freshman-level introduction to Robotics, motivating later courses. RBE 2001–3002 provides a sophomore/junior-level unified treatment of sensing, computation, and actuation, incorporating concepts from CS 2102, CS 2303, ECE 2022, ECE 2280, ES 2501 and ES 2503 applied to Robotics. The Unified Robotics sequence will revisit topics introduced in RBE 1001, exploring in depth topics that were only touched upon initially.

Table 1 shows the proposed new course implementation schedule. ES 2201 is currently being offered in Terms A and B 2006, enrolling 77 students total. Any of these students who wish to pursue the RBE major will be able to start the Unified Robotics sequence beginning C term 2008. The RBE 2001 and 2002 offerings in Spring 2008 give us the opportunity to offer the starting half of the Unified Robotics sequence to a small number of students, allow for revision before the program fully ramps up, and allow students currently taking ES 2201 to convert to RBE majors if they desire to do so. We propose to introduce the second half of the Unified Robotics sequence a year later, allowing for development of all courses over time instead of all-at-once. Starting in 2008-09, RBE 1001 will be offered twice yearly and the Unified Robotics courses will be offered once yearly.

Table 1: New Course Schedule

Year	A Term	B Term	C Term	D Term
2006-07	**RBE 1001 (ES 2201)**	**RBE 1001 (ES 2201)**		
2007-08		**RBE 1001**	**RBE 2001**	**RBE 1001** **RBE 2002**
2008-09 and Thereafter	**RBE 2001**	**RBE 1001** **RBE 2002**	**RBE 3001**	**RBE 1001** **RBE 3002**

Additional offerings of the Unified Robotics sequence may be added as justified by enrollment. For example, one could add C, D, A, B Term offerings of RBE 2001 through RBE 3002, respectively. The sample programs below illustrate the normal track, which enters the Unified Robotics sequence at the beginning of the sophomore year, and an alternative track that delays the Unified Robotics sequence until mid-sophomore year, for example, due to change of majors or transfer to WPI from elsewhere.

Additional courses may be introduced as justified by enrollment.

4.2.3 ROBOTICS ELECTIVES

Robotics electives are included in the program to give students the opportunity to delve more deeply into some aspects of engineering that relate to robotics. Students may focus their electives in a single area such as CS, ECE, or ME, or, if they prefer, remain robotics generalists. We emphasize that concentration within a robotics subfield is not required. In any case, courses on the Robotics Electives list, referred to in Distribution Requirement Note 8, should help students prepare for project work and/or further study. As an initial list of electives, we propose the following set:

CS 2303 System Programming Concepts
CS 3013 Operating Systems
CS 3041 Human-Computer Interaction
CS 4341 Introduction to Artificial Intelligence
CS 4514 Computer Networks: Architecture and Implementation

ECE 2311 Continuous-time Signal and System Analysis
ECE 2312 Discrete-time Signal and System Analysis
ECE 3308 Introduction to Wireless Networks

ME 3310 Kinematics of Mechanisms
ME 4322 Modeling and Analysis of Mechatronic Systems
ME 4815 Industrial Robots

Appropriate graduate courses may be substituted, subject to advisor approval.

Students must select at least three courses from this list. Some of these courses have recommended backgrounds that exceed what is covered under Distribution Requirements. In such cases, students may use elective courses or independent study to acquire the necessary background.

At least one of the selected courses must be in Advanced Systems (CS 4341, ECE 3308, ME 3310) to ensure depth in some subarea of robotics.

The Robotics Electives list may be revised by the Associated Faculty as courses are added, dropped, and revised.

4.2.4 SAMPLE PROGRAMS

Table 2 shows a sample program for a typical student who takes RBE 1001 in the 1st year and Unified Robotics I–IV in the 2nd year. Table 3 shows an alternative sample program for someone who delays entry to Robotics by taking RBE 1001 D Term freshman year and continuing with RBE 2001 in the 2nd half of the 2nd year. This alternative program may only become available after enrollment has increased to the point at which additional offerings of Unified Robotics are justified.

Table 2: Typical program

Year	A Term	B Term	C Term	D Term
Freshman	**MA 1021** **PH 1110/1** **CS 1101/2**	**MA 1022** **PH 1120/1** **RBE 1001**	**MA 1023** **PH 2201** **HU**	**MA 1024** **ECE 2022** **HU**

Sophomore	**RBE 2001** **ECE 2801** **HU**	**RBE 2002** **MA 2051** **CS 2223**	**RBE 3001** **ES 3011** **SS**	**RBE 3002** **SS** **HU**
Junior	**ETR 3910** **HU** **IQP**	**MA 2611** **HU-SUFF** **IQP**	**MA 2071** **Robotics Elective 1** **IQP**	**Social Issues** **Robotics Elective 2** **CS 3733**
Senior	**Science** **Robotics Elective 3** **MQP**	**Free Elective 1** **Free Elective 2** **MQP**	**Free Elective 3** **Phys Ed (4/12)** **MQP**	

Table 3: Alternative program

Year	**A Term**	**B Term**	**C Term**	**D Term**
Freshman	**MA 1021** **PH 1110/1** **HU**	**MA 1022** **PH 1120/1** **HU**	**MA 1023** **CS 1101** **HU**	**MA 1024** **RBE 1001** **HU**
Sophomore	**PH 2201** **HU** **Science**	**MA 2051** **HU-SUFF** **ECE 2022**	**RBE 2001** **ECE 2801** **SS**	**RBE 2002** **CS 2223** **SS**
Junior	**RBE 3001** **ES 3011** **IQP**	**RBE 3002** **MA 2071** **IQP**	**Social Issues** **Robotics Elective 1** **IQP**	**MA 2611** **Robotics Elective 2** **CS 3733**
Senior	**Robotics Elective 3** **ETR 3910** **MQP**	**Free Elective** **Free Elective** **MQP**	**Free Elective** **Phys Ed (4/12)** **MQP**	

4.3 ACCREDITATION CONSIDERATIONS

Robotics Engineering is not recognized by ABET as a distinct engineering discipline, hence there are no program-specific criteria to follow for accreditation. Nonetheless, we have planned the program as if it were accreditable, based on program objectives and outcomes, and with mathematics, science, and engineering and design components consistent with general criteria for accreditation. Such a program is potentially accreditable under General Engineering, which has no program-specific criteria, and we expect to apply for accreditation eventually[3].

Program criteria for Mechatronics Engineering are currently under consideration by ABET. These criteria refer to required chemistry and materials components, which we have not included in our program. Hence, despite the similarities between Mechatronics and Robotics, accreditation using Mechatronics Engineering criteria appears infeasible.

The ABET Engineering Accreditation Commission defines general criteria that all accreditable programs must satisfy[4]. The general criteria require program educational outcomes and objectives.

[3] ABET requires at least one person to have graduated under the program requirements in order to accredit a program.

[4] http://www.abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2006-07%20EAC%20Criteria%205-25-06-06.pdf

These are given in APPENDIX I and APPENDIX II. The professional component must include one year of math and science and one and one-half years of engineering topics. WPI generally interprets one year of study as 3 courses/term × 4 terms = 12 courses. However, ABET allows one to define a year of study as ¼ of the total degree requirement, in our case, 45 units, thus 11.25 courses. Because the Robotics Engineering degree requirements are very tight, we opt to require 11 Math and Science courses. The 6 units of required Engineering Science and Design activities are the same as for other WPI ABET accredited programs.

4.4 RESEARCH

We anticipate that the development of a Robotics Engineering major will lead to significant robotics research at WPI. Indeed, it would be a pre-requisite for tenure for any probationary faculty hires. This research should lead to increase visibility and enhanced reputation for WPI, leading to increased enrollment in RBE and other disciplines.

Research contributes to revenue generation via indirect cost recovery and additional RA tuition for supported graduate students. With the high research potential for Robotics, each faculty member may be assumed to secure, on average, his/her annual salary in external support, of which 1/3 represents indirect costs with 85% of that going to Academic Affairs and 15% to the PI and departments.

4.5 THE ROBOTICS INDUSTRY

> *The epicenter of Robotics is in New England.*
>
> Helen Greiner, CEO, iRobot Corp[5]

New England, and Massachusetts in particular, houses a strong and growing Robotics industry. The state boasts over 150 companies, institutions, and research labs in the robotics sector, employing over 1,500 people and with over $250M in annual sales of robots and components[6]. APPENDIX III lists some New England companies involved in Robotics. Several prominent industry leaders have already agreed to serve on the Advisory Board for the Robotics Engineering program (see APPENDIX IV). By implementing the Robotics Engineering major, WPI will not only contribute to the region's reputation as the center of the robotics industry, but to WPI's reputation as well.

4.6 COMPETING PROGRAMS

Many universities offer courses in Robotics. Some, including WPI, offer concentrations or similar, such as minors, clusters, threads, and focus areas. As far as we know, no university in the U.S. offers an undergraduate degree in Robotics, although Plymouth (U.K.) University has been offering a Robotics and Automation B.Sc. course since 2004 with an emphasis on industrial robotics.

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[5] Personal Communication.

[6] "Massachusetts Innovation Leadership", Mass Technology Leadership Council, 2006.

At the graduate level, CMU offer M.S. and Ph.D. degrees in Robotics, USC offers an M.S. program in Intelligent Robotics, and GA Tech recently announced the establishment of the Center for Robotics and Intelligent Machines at Georgia Tech to serve as a center for robotics research and education.

4.7 POTENTIAL STUDENT INTEREST

There is a large body of high school students nationwide with interest in robotics. WPI can attract many of these talented students with an innovative Robotics Engineering program. As indicators of the level of interest, we cite the following statistics:

- In 2006, over 28,000 high-school students competed in FIRST Robotic Competition and another 6,000 mostly high school students competed in FIRST Vex Challenge[7].
- FIRST Robotic Competition expects to reach over 30,000 high-school aged students in 2007[8] and FIRST Vex Challenge projects to reach over 25,000 students within a few years[9]
- Botball robotic soccer competitions have included over 34,000 students to date[10].
- BattleBots IQ (numbers unknown) has been going on since 2000, claiming to have "hundreds" of high schools involved. WPI won the 2006 College Large Division National Championship[11].
- Other robotics events, such as Robocup (numbers unknown) and Boosting Engineering, Science and Technology (BEST) Robotics with 8,000 students yearly[12], also illustrate the high level of interest.
- The robots.net Robotics Competition page lists 88 competitions in 2006 alone.[13] Note that FIRST counts as a single entry, despite its multiple dates and venues.

Within WPI, many entering students express an interest in robotics every year. For example, over the last 12 months, over 130 visiting prospective students listed robotics either as a principal interest area or as their planned major on WPI Admissions Information forms. In Fall 2005 and 2006, 96 and 101 freshmen, respectively, joined the WPI Robotics Team. One-third of them stated an interest in pursuing robotics for their MQP or academic major at WPI. 43% had known of the

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[7] http://www.usfirst.org/about/2006/FIRST_FAQ_2006_3.pdf

[8] http://www.usfirst.org/robotics/

[9] FIRST Vex Challenge officials teleconference communication to Ken Stafford.

[10] Botball Statistics and Numbers, http://www.botball.org/about-botball/statistics_and_numbers.php

[11] http://www.battlebotsiq.com/news.php

[12] http://www.bestinc.org/MVC/About/what_is_best

[13] http://robots.net/rcfaq.html

WPI/FIRST/robotics connection before enrolling at WPI and 62% of these indicated that this knowledge was a strong positive reason for selecting WPI.

Course ES 2201 Introduction to Robotics, offered for the first time in Terms A and B 2006, has enrollment of 41 and 36 students, respectively despite its late addition to the curriculum and its absence from the printed Undergraduate Catalog.

The Robotics Engineering program will enjoy a unique advantage over other new programs. Our target audience has already assembled itself into well-defined organizations based on robotics competitions. These organizations have well-defined lines of communications with all constituents whose demographics match our target pool exactly. Thus, there is an extremely low cost to reach this audience, an audience which is uniformly predisposed to our message.

The potential applicant pool is measured in the 10's of thousands. WPI already draws a significant number of robotics students despite having only a rudimentary, non-cohesive set of course offerings. With a complete Robotics Engineering B.S. degree program, having *no domestic competitors*, we will attract even more highly talented, qualified, and motivated students to WPI.

4.8 ENROLLMENT PROJECTIONS

The following figures are educated guesses only. More accurate enrollment projections are difficult to obtain. We expect 20-30 students to enroll in Robotics Engineering in the 1st year, with yearly freshmen enrollment targets of 30-40 (low) to 40-50 (high) thereafter, for a steady state enrollment of 120-200 students total.

We conservatively assume that 1/3 of Robotics Engineering majors are students drawn to WPI by RBE, i.e., they would not have attended WPI otherwise. In the steady state, we expect this contribution to be at least 10-15 new students each year, i.e. 40-60 students over 4 class years. We assume 5 new students in the 1st year, 10 new students in the 2nd year, and 15 new students thereafter. These numbers can be increased through effective marketing beyond New England. Dean Kamen has offered to help attach WPI Robotics Engineering to US FIRST.

4.9 SYNERGIES

> *Robotics is the ultimate interactive media.*
>
> Russell Tedrake, Assistant Professor, MIT EECS[14]

Robotics Engineering syngergizes well with Interactive Media and Game Development. The two programs share a common theme: the close interaction of humans with computational systems. The former emphasizes autonomous systems performing physical tasks for humans; the latter emphasizes semi-autonomous systems generating virtual worlds for humans.

[14] Personal Communication. One of us (MAG) had asked Dr. Tedrake why he, a roboticist, was interested in interactive media. "Mike, you don't get it. Robotics is the ultimate interactive media." (He gets it now.)

The pool of students interested in either has a natural affinity for the other. As the avant-garde of engineering students, they are apt to share certain characteristics: unconventionality, risk-taking, and high motivation. They will find the flexibility of a late choice yet another attraction to WPI vs. institutions that now offer—or plan to offer— one or the other major. RBE and IMGD lend themselves well to double-majors, as would any of CS, ECE, MA, ME, and PH. For those programs that offer minors, an RBE major with a minor in an allied field would also be an attractive combination.

Although not a focus of the current proposal, the application of robotics to Biomedical Engineering also holds much promise via prosthetic devices, surgical instruments, and assistive technologies. This adds another dimension to the human–machine interaction themes of RBE and IMGD.

B.S./M.S. students should be allowed to continue from RBE to CS, ECE, or ME for graduate studies, allowing more in-depth work in a specialty than is possible within the constraints of the RBE B.S. program. This should be strongly encouraged, both for the educational value, and for the potential to turn MQPs into more enduring contributions through M.S. theses and research publications.

We expect that highly innovative research will take place in the form of collaboration among faculty and students in Robotics Engineering and the other engineering disciplines and IMGD. The result will be high profile exposure for all programs concerned, enhanced funding opportunities, and increased educational cooperation.

5 REQUIRED RESOURCES

5.1 FACULTY

At present, no faculty members have primary interest in Robotics. Thus, it will be necessary to hire a core of faculty for the program. Over the first 2-3 years of the program, we plan to hire one faculty member from each of CS, ECE, and ME. One of these will be at the associate or full professor level to serve as the Program Director. We should consider tenure on arrival as an incentive for an extraordinarily well-qualified candidate. The other faculty hires may be junior level.

5.2 LABORATORY

Robotics Engineering begs a dedicated, highly visible, showcase teaching laboratory. The lab will be used for the introductory Robotics course, the Unified Robotics course sequence, the Robotics Design course, and Robotics MQPs. With 120-200 student taking 5 Robotics courses / 16 terms, the average load will be 35-60 students / term, not including projects. The current "Robotics Laboratory" in Washburn Shops is completely utilized for CNC machining, robots used in the ME senior course ME 4815 Industrial Robotics, and project work, and cannot accommodate the expected additional student load. Laboratory space requirements are not yet determined.

We propose to put the Robotics Laboratory in Salisbury Laboratories 1st floor adjacent to the proposed Interactive Media and Game Development laboratory. This location will facilitate Robotics Engineering and IMGD interaction, encouraging innovative research, courses and projects on the interaction of humans and machines. We also propose using space in Salisbury Laboratories 2nd floor for research and projects.

5.3 OTHER

We propose to hire a full-time Robotics Lab Manager and a half-time Administrative Assistant for the program. Other expenses include supplies, travel, equipment, and course development costs.

6 MANAGEMENT

6.1 LEADERSHIP

The Robotics Engineering program will have a director and an associate director. The associate director will be from a department other than the director (e.g., if the director is from the Computer Science Department, the associate director could be from the Electrical & Computer Engineering or Mechanical Engineering Department). The director and the associate director will be appointed by the Provost. Faculty hired for the Robotics Engineering program will be in an existing WPI academic department. For issues such as faculty governance, promotion and tenure, the faculty member will be treated as a member of this academic department.

There will be a Steering Committee comprising the Director, Associate Director and the Department Heads of the CS, ECE, and ME Departments, or their designees. The Steering Committee will assist in the continued development of the program and will also provide any additional functionality required for the Robotics Engineering program, such as course scheduling, program review, outcome assessment, list of associated faculty, etc.

Associated Faculty for the program are responsible for most of the program operations, including teaching, research, and academic and project advising. The initial list of Associated Faculty is given in APPENDIX V

6.2 IMPLEMENTATION

Fall 2006:

Complete proposal.

Offer ES 2201 Introduction to Robotics.

Approval by WPI faculty and administration.

Develop marketing materials.

Submit NSF IISCD proposal.

Recruit high school seniors.

Spring 2007:

Submit NSF CCLI proposal.

Summer 2007:

Develop courses.

Fall 2007:

Enroll 1st student cohort.

Offer RBE 1001 Introduction to Robotics.

Spring 2008:

Hire Program Director.

Offer RBE 1001 Introduction to Robotics.

Offer RBE 2001 Unified Robotics I, RBE 2002 Unified Robotics II.

Summer 2008:

Additional course development

Fall 2008:

Enroll 2nd student cohort.

Offer RBE 1001 Introduction to Robotics.

Offer RBE 2001 Unified Robotics I, RBE 2002 Unified Robotics II.

Spring 2009:

Recruit additional faculty.

Offer RBE 1001 Introduction to Robotics.

Offer RBE 3001 Unified Robotics III, RBE 3002 Unified Robotics IV.

AY 2009-2010:

Expect first RBE student to graduate.

Prepare for accreditation.

Continue course offerings as above.

Summer 2010:

Submit accreditation materials to ABET.

APPENDIX I. PROGRAM OBJECTIVES

The Robotics Engineering Program strives to educate men and women to

- Have a basic understanding of the fundamentals of Computer Science, Electrical and Computer Engineering, Mechanical Engineering, and Systems Engineering.

- Apply these abstract concepts and practical skills to design and construct robots and robotic systems for diverse applications.

- Have the imagination to see how robotics can be used to improve society and the entrepreneurial background and spirit to make their ideas become reality.

- Demonstrate the ethical behavior and standards expected of responsible professionals functioning in a diverse society.

APPENDIX II. PROGRAM OUTCOMES

Graduating students will have

- an ability to apply broad knowledge of mathematics, science, and engineering,
- an ability to design and conduct experiments, as well as to analyze and interpret data,
- an ability to design a robotic system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability,
- an ability to function on multi-disciplinary teams,
- an ability to identify, formulate, and solve engineering problems,
- an understanding of professional and ethical responsibility,
- an ability to communicate effectively,
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context,
- a recognition of the need for, and an ability to engage in life-long learning,
- a knowledge of contemporary issues, and
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

APPENDIX III. INDUSTRIAL CONNECTIONS

The following lists a few of the Robotics companies in New England:

- Alceon Corp, http://www.alceon.com/alceon.html
- AlvaMed LLC, http://www.alvamed.com/
- Black-I Robotics, http://www.blackirobotics.com/
- Bluefin Robotics Corporation, http://www.bluefinrobotics.com/
- Boston-Engineering, http://www.boston-engineering.com/
- Brooks Automation, http://www.brooks.com/
- DEKA Research and Development Corp., http://www.dekaresearch.com/
- Focus Robotics, http://www.focusrobotics.com/
- Foster-Miller, http://www.foster-miller.com/
- ID One, Inc., http://www.idoneinc.com/index.htm
- iRobot Corp., http://www.irobot.com/
- Kiva Systems, http://www.kivasystems.com/index.html
- MobileRobots, http://robots.mobilerobots.com/
- Segway, http://www.segway.com/
- TIAX LLC, http://www.tiaxllc.com/
- Valde Systems, Inc., http://www.valdesystems.com/

APPENDIX IV. ADVISORY BOARD

The following individuals have agreed to serve on the Robotics Engineering Advisory Board:

- Brian Abraham, President, Bluefin Robotics
- Helen Greiner, Co-founder and Chairman of the Board, iRobot Corp.
- Brian Hart, President, Black-I Robotics.
- Dean Kamen, Founder and President, DEKA Research and Development Corp.
- Dan Kara, President, RoboticsTrends.

APPENDIX V. ASSOCIATED FACULTY

- Holly Ault, ME
- David C. Brown, CS
- Michael Ciaraldi, CS
- David Cyganski, ECE
- Michael Demetriou, ME
- R. James Duckworth, ECE
- Mustapha Fofana, ME
- Cosme Furlong, ME
- Michael A. Gennert, CS
- Allen Hoffman, ME
- Xinming Huang, ECE
- Islam Hussein, ME
- Susan Jarvis, ECE
- Robert Lindeman, CS
- Robert Norton, ME
- Gary Pollice, CS
- Yiming (Kevin) Rong, ME
- Lance Schachterle, Provost's Office
- Kenneth Stafford, ME
- Gretar Tryggvason, ME