Session ENG 205-085

Mechatronics Engineering: A Critical Need for This Interdisciplinary Approach to Engineering Education

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Abstract

Southern Polytechnic State University has proposed a new degree program in Mechatronics Engineering. This paper presents the global status of undergraduate programs in Mechatronics Engineering and the critical need for this degree offering in the United States. The primary objective of the interdisciplinary Mechatronics degree is to meet industry requirements for graduates with the knowledge of integration of mechanical engineering, electrical engineering, and control systems. Discussions on new approaches to classical engineering education to better meet the requirements of industry will hopefully result.

Introduction

The Bachelor of Science in Mechatronics Engineering (BSMtrE) degree proposed by Southern Polytechnic State University (SPSU) will be the first offering of this degree within the state of Georgia. The primary objective of the interdisciplinary BSMtrE degree is to meet industry requirements for graduates with knowledge of integration of mechanical engineering, electrical engineering, and control systems. Industry has identified a need for engineers with knowledge of this integration.

The term "mechatronics" was first introduced in Japan in 1969 to describe the integration of mechanics and electronics [1][2][3]. The term is widely used in Europe and is generally understood by engineers in the U.S., but is less recognized by the general public. There is only one undergraduate mechatronics engineering degree program in the U.S. that is accredited by the Accreditation Board for Engineering and Technology (ABET). ABET has recognized the emerging importance of mechatronics engineering and has recently proposed specific evaluation criteria for "Mechatronics Engineering and similarly named programs" that are in the review process [4].

Today's perspective of Mechatronics has evolved with technology. At SPSU we use the industry evolved definition of Mechatronics adopted by the IEEE/ASME Transactions on Mechatronics [5]:

- The synergistic integration of mechanical engineering with electronics.

- Intelligent computer control in the design and manufacture of products and processes.
- The blending of mechanical, electronic, software, and control theory engineering topics into a unified framework that enhances the design process.

The multiple disciplines involved with mechatronics are shown in **Figure 1**.

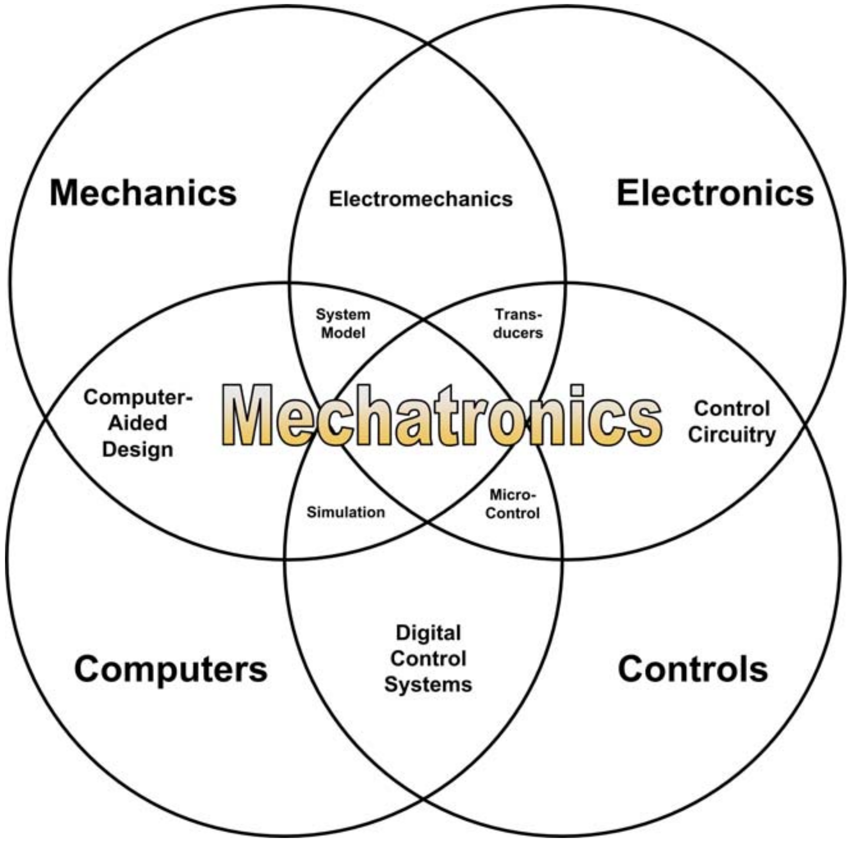


Figure 1 - Disciplines of Mechatronics

The specific objectives of the SPSU BSMtrE degree are to provide engineering graduates that:

- Understand the interdisciplinary fundamentals of mechanical engineering, electrical engineering, control systems, and their integration.
- Have strong team skills to solve complex problems that cross disciplinary boundaries.
- Perform research, design, and implementation of intelligent engineered products and processes enabled by the integration of mechanical, electronic, computer, and software engineering technologies.

In order to understand the justification and need for Mechatronics Engineering, it is important to discuss what mechatronics is, how it has developed, and where it is applied.

Mechatronics Defined - Interdisciplinary Engineering Education

IEEE/ASME Transactions on Mechatronics was the first refereed journal published in the United States focused on Mechatronics. In the first issue (March 1996), mechatronics was defined as: "The synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes." [6] The ten specific topics identified under the general category of mechatronics are shown in **Table 1**:

Table 1 - Specific Topics of Mechatronics Engineering

• modeling and design	• motion control
• system integration	• vibration and noise control
• actuators and sensors	• micro devices and optoelectronic systems
• intelligent control	• automotive systems
• robotics	• manufacturing

Mechatronic systems can be a complete product or a sub-component of a product. Examples of mechatronic systems include aircraft flight control and navigation systems; automotive electronic fuel injection and anti-lock brake systems; automated manufacturing systems including robots, numerical control machining centers, packaging systems and plastic injection-molding systems; artificial organs; health monitoring and surgical systems; copy machines; and many more. Some common element of all these systems is the integration of analog and digital circuits, microprocessors and computers, mechanical devices, sensors, actuators, and controls.

Mechatronics Engineering graduates can select from a wide spectrum of industries for career choices and can also contribute in a variety of roles including design engineer, software engineer, project planner, product designer, and project manager. Mechatronics Engineering program graduates are able to select from jobs as Mechatronics specialists in a variety of industries. Opportunities will also be available to graduates in smaller companies that need generalists who can perform both mechanical and electrical engineering functions.

Mechatronics Engineering - The Need in Industry

The National Science Board (NSB) publishes Science and Engineering Indicators for the U.S. every two years. The NSB observed alarming trends in the data published in Indicators 2004 and published a companion report [19]. One of the key observations made in the report was: "we have observed a troubling decline in the number of U.S. citizens who are training to become scientists and engineers, whereas the number of jobs requiring science and engineering (S&E) training continues to grow." The report editors were compelled to issue a warning: "These trends threaten the economic welfare and security of our country." A previously published report NSB 03-69, 2003 drew similar conclusions. The NSB report estimates the number of U.S. jobs requiring S&E skills is growing about 5% per year, compared to a 1% growth for the rest of the labor force. Concern is also expressed over foreign competition. The

NSB states that other countries have made increased S&E education investments at higher rates than the U.S.

As previously discussed, Mechatronics Engineering will lead to more technological innovations due to interdisciplinary thinking. An example of this can be found by looking at the packing machinery industry. The Packaging Machinery Manufacturers Institute is a trade association whose more than 500 members manufacture packaging and packaging-related converting machinery in the United States and Canada. U.S. packaging machinery shipments reached $5.344 billion in 2004, a 9.3 percent increase over 2003. Two reasons cited for this growth are: 1) increased emphasis on expanding packaging line automation when customers added fully automatic or semi automatic machines where none had been before or upgraded from semi-automated to fully automated machinery and 2) demand creation through a favorable market reception to technological innovation and new model design. Primary benefits gained from the advanced technology were increased speed and output, higher efficiency, expanded flexibility, improved product handling, greater accuracy, simpler control, and more versatile handling through robotics [22].

Douglas Machine, a PMMI member, manufactures complex packaging machines and is a regional partner of the Center for Automation and Motion Control (CAMC) in Alexandria, MN. Douglas has stated that their competitors in Germany and Italy are benefiting from an earlier commitment by their industries and their governments' support for a mechatronic curriculum. Advancing beyond the mechanical timing paradigms of the past, Mechatronic Engineers are able to design and manufacture the "next generation" of advanced packaging machines [23]. "It's quite possible that within the next five years, there won't be a machine made that doesn't use mechatronics in some aspect of its operation," says Dr. Ken Ryan, director of the CAMC [24]. In April 2003, Keith Campbell, Executive Director of the Open Modular Architecture Controls (OMAC) Packaging Workgroup, stated "many of our members believe that the USA lags behind European countries in the development of machines based upon these technological advances [25]." OMAC is a 500 member organization founded in 1997 by manufacturing technology leaders in automotive, aerospace and related metalworking industries through which companies work together to promote development and adoption of open automation controls.

The Society of Manufacturing Engineers (SME) conducted studies in 1997, 1999, and 2002 to determine competency gaps between manufacturing industry's workforce needs and what is provided by educational programs. Manufacturing Systems and Manufacturing Process Control are two high priority competency gaps identified in each study and were earmarked for focus in the 2005 Manufacturing Education Plan [26]. A Mechatronics Engineering graduate will have knowledge of and be capable of applying engineering principles for design, modeling, and implementation of manufacturing automation systems and manufacturing process control. Availability of graduates in Mechatronics Engineering will help industry reduce the identified critical competency gaps.

The next few years will witness a continued demand for engineering jobs. "There is this myth that the last thing you should do is go into engineering," says Diana Farrell, head of McKinsey

Global Institute (MGI). "But the underlying growth of demand for engineers is so great that even when you consider the potential of offshoring, there will be demand in the U.S [27]." MGI was founded in 1990 to research critical economic issues facing businesses and governments around the world.

Tim Foutz, a professor and undergraduate engineering program coordinator in the University of Georgia, College of Agricultural and Environmental Sciences, said "According to national data, engineering and technical jobs are increasing at five times the rate of any other work force. A lot of current engineers are reaching retirement age. Plus, the United States imports 12-15 percent of its engineers, and Georgia is at the lead of that trend. The demand for engineers is there." [28].
Thomas S. Moore, general manager for technical affairs at Chrysler Corporation in Madison Heights, Michigan was quoted as saying "I believe that mechanical engineers with a mechatronics background will have a better chance of becoming managers. We see mechatronics as the career of the future for mechanical engineers." [9]

John F. Elter, vice president of strategic programs at Xerox Corp. in Webster, N.Y believes "Classically trained mechanical engineers will run the risk of being left out of the interesting work. At Xerox, we need designers who understand the control theory well enough to synthesize a better design. These people will have much more of a chance to lead. One possibility is that the mechatronics practitioner will prototype the whole design, then the specialists in the various disciplines will take over the detail design." [9]

The Need for Interdisciplinary Education

Many engineered products and processes are developed by integrating multiple technologies into a problem solution [6]. These technologies often span a variety of disciplines, thereby increasing the complexities of design problems faced by engineers. If an engineering design team is composed of individuals trained in the classic disciplines (mechanical engineering, electrical engineering, chemical engineering …), it will be difficult to provide the best design solution for interdisciplinary problems [6]. Mechatronics advances the ideas of interaction further with interdisciplinary thinking by individual engineers in addition to the multi-disciplinary team approaches. Tomizuka [8] supports this conclusion by stating "Mechatronics may be interpreted as the best practice for the synthesis of engineering systems". Kevin Craig, Professor of Mechanical Engineering in the Department of Mechanical, Aerospace, and Nuclear Engineering at Rensselaer Polytechnic Institute, states: "Mechatronics does not change the design process. It gives the engineer greater knowledge, so the concepts that are developed are better, and communication with other engineering disciplines is improved. The result is a highly balanced design [9]."

Van Brussel, a robotics researcher, also supports mechatronics interdisciplinary education. In the IEEE/ASME Transactions on Mechatronics, Van Brussel wrote: "In the past, machine and product design has, almost exclusively, been the preoccupation of mechanical engineers. Solutions to control and programming problems were added by control and software engineers, after the machine had been designed by mechanical engineers. This sequential-engineering approach usually resulted in suboptimal designs. Recently, machine design has been profoundly influenced by the evolution of microelectronics, control engineering, and computer science. What is needed, as a solid basis for designing high-performance machines, is a synergistic cross-fertilization between the different engineering disciplines. This is exactly what mechatronics is aiming at; it is a concurrent-engineering view of machine design [10]."

The lack of interdisciplinary education and its importance are claimed by Mayer-Krahmer [11]. Studies discussed by Mayer-Krahmer have concluded that technology should not be separated into the discrete classic disciplines. Mechatronic innovations are often stimulated from an integrated discipline approach as opposed to the composite of disparate disciplines [12]. The full potential of interdisciplinary solutions results from bridging the gap between product technologies and engineering disciplines [11][13]. In other studies by: 1) Association of American Colleges and Universities 2002 [14]; 2) National Research Council 2002 [15], 3) National Research Council 2003a [16]; 4) National Research Council 2003b [17]; and 5) Project Kaleidoscope 2002 [18]; science and engineering educators are urged to move toward more interdisciplinary education.

Mechatronics Engineering Education Around the World

There are no undergraduate Mechatronics Engineering programs in the State of Georgia. Mechatronics has been evolving in industry and education since its definition in 1969 and is now widely recognized around the world. The Accreditation Board of Engineering and Technology (ABET) / Engineering Accreditation Commission (EAC) is charged with engineering education accreditation in the United States. The Washington Accord is an agreement between ABET and the similar accrediting agencies in Australia, Canada, Hong Kong, Ireland, Japan, New Zealand, South Africa, and the United Kingdom. The members of the accord recognize the substantial equivalency of accreditation systems of organizations holding signatory status and the engineering education programs accredited by them. Table 2 lists the accrediting agencies that participate in the Washington Accord.

Table 2 - Accreditation Agencies Recognized by the Washington Accord

Agency Abbrev.	Accrediting Agency Name
IEA	The Institution of Engineers Australia
HKIE	The Hong Kong Institution of Engineers
EI	Engineers Ireland
ENZ	Engineers New Zealand
ECSA	Engineering Council of South Africa
ECUK	Engineering Council United Kingdom
ABET/EAC	Accreditation Board for Engineering & Technology / Engineering Accreditation Commission
CDPE	Canadian Council of Professional Engineers
JABEE	Japan Accreditation Board for Engineering Education

Table 3 lists undergraduate mechatronic degrees recognized through the Washington Accord. In the July 2002 issue of the Journal of Engineering Education [20], Shooter and McNeill state that engineering curricula internationally are recognizing the need to develop engineers that are proficient across traditional engineering fields. The 42 Mechatronic Engineering Programs recognized by ABET shown in Table 3, representing seven countries, support Shooter and McNeill's conclusions.

Table 3 - Undergraduate Mechatronic Degrees Recognized by ABET / EAC

Institution	**Degree Name** **BS - Bachelor of Science** **BEng - Bachelor of Engineering** **BME - Bachelor of Mechanical Eng.**	**Agency (See** Table 2**)**	**First Accredited**
Australian National University, Canberra, Australia	BEng Mechatronics Systems	IEA	2002
Curtin University of Technology, Perth Australia	BEng Mechatronic Engineering	IEA	1998
Deakin University, Australia	BEng Mechatronics	IEA	1996
Deakin University Singapore Pathway, Australia	BEng Mechatronics	IEA	1997
James Cook University of North Queensland, Australia	BEng Mechatronics Engineering	IEA	1996
Monash University, Clayton, Australia	BEng Mechatronics Engineering	IEA	2003
Monash University, Gippsland, Australia	BEng Mechatronics Engineering	IEA	1999
Monash University, Malaysia	BEng Mechatronic Engineering	IEA	2001
Swinburne University of Technology, Hawthorn, Australia	BEng Robotics and Mechatronics	IEA	1999
University of Adelaide, Adelaide, Australia	BEng Mechatronic Engineering	IEA	1997
The University of Newcastle, Callaghan, Australia	BEng Mechatronics Engineering	IEA	2000
The University of Newcastle Singapore Pathway, Australia	BEng Mechatronics Engineering	IEA	2001
The University of New South Wales, Sydney, Australia	BEng Mechatronics Engineering	IEA	1980
The University of Queensland, Brisbane, Australia	BEng Mechatronic Engineering	IEA	2002
University of Southern Queensland,	BEng Mechatronic	IEA	1995

Institution	Degree Name BS - Bachelor of Science BEng - Bachelor of Engineering BME - Bachelor of Mechanical Eng.	Agency (See Table 2)	First Accredited
Toowoomba, Australia	Engineering		
University of Sydney, Sydney, Australia	BEng Mechatronic Engineering	IEA	1991
University of Tasmania, Hobart, Australia	BEng Mechatronics Engineering	IEA	2001
The University of Western Australia, Perth, Australia	BEng Mechatronics	IEA	2000
University of Western Sydney, Sydney, Australia	BEng Robotics and Mechatronics	IEA	1999
University of Wollongong, Wollongong, Australia	BEng Mechatronics	IEA	2002
City University of Hong Kong, Kowloon, Hong Kong	BEng Degree in Mechatronic Engineering	HKIE	
Dublin City University, Dublin, Ireland	BEng in Mechatronic Engineering	EI	
Massey University, Albany, New Zealand	BEng Mechatronics	ENZ	1999
University of Cape Town, South Africa	BS in Engineering Mechatronic Engineering	ECSA	1997
Blackpool & The Fylde College, UK	BEng Mechatronics	ECUK	2004
Brunel University, UK	BEng Integrated Engineering Mechatronics	ECUK	1998
University of Hull, UK	BEng Mechatronics	ECUK	1992
East Lancashire Institute of Higher Education Blackburn, UK	BEng Mechatronics	ECUK	2004
University of Lancaster, UK	BEng Mechatronic Engineering	ECUK	1987
University of Lancaster, UK	BEng Mechatronic Systems Engineering	ECUK	1986
Liverpool John Moores University - Liverpool Polytechnic, UK	BEng Integrated Engineering Mechatronics	ECUK	1999
University of London - King's College, UK	BEng Mechatronics	ECUK	1998
University of Manchester, UK	BEng Mechatronic Engineering	ECUK	2005

Institution	Degree Name BS - Bachelor of Science BEng - Bachelor of Engineering BME - Bachelor of Mechanical Eng.	Agency (See Table 2)	First Accredited
Manchester Metropolitan University - Manchester Polytechnic, UK	BEng Mechatronics (Automation & Control)	ECUK	1997
University of Newcastle upon Tyne, UK	BME with Mechatronics	ECUK	1997
Sheffield Hallam University - Sheffield City Polytechnic, UK	BEng Mechatronics	ECUK	1996 (2002)
Staffordshire University - North Staffordshire Polytechnic, UK	BEng Mechatronics	ECUK	1996 (2002)
University of Surrey, UK	BME with Mechatronics	ECUK	1991
University of Sussex, UK	BEng Mechatronics	ECUK	1996
Napier University - Napier Polytechnic of Edinburgh, UK	BEng Mechatronics	ECUK	2004
Glamorgan University - Polytechnic of Wales, UK	BEng Mechatronic Engineering	ECUK	1995
California State University, Chico, CA	BS in Mechatronics Engineering	ABET/ EAC	1998

Mechatronics Engineering Education in the United States

In the United States, Mechatronics Engineers tend to emerge from masters degree programs after a first degree in mechanical or electrical engineering [21]. There is only one U.S. undergraduate program offering an ABET accredited degree in mechatronics; California State University, Chico – Bachelor of Science in Mechatronics Engineering. Beginning fall semester 2005, Colorado State University in Pueblo has offered a Bachelor's of Engineering in Mechatronics with the goal of ABET accreditation in 2011. Of the forty-two accredited (or equivalent) Bachelor's degrees in mechatronics recognized by ABET, only ***one*** degree is from a university in the United States. Hsu stated in the April 1999 Journal of Engineering Education that "The need for formalized mechatronics education in the US is thus long overdue" [21]. In his study, he concluded "there is a clear need for BS engineering graduates with knowledge and skill in mechatronics by American industry."

While there is a lack of undergraduate Mechatronics programs in the United States, there has been a lot of research on the subject of mechatronics. The National Science Foundation has made forty-six mechatronic grant awards since 1992 for $6.5 million as shown in Table 4. There have been many more awards related to mechatronics technology (i.e., robotics, automated manufacturing, motion control, etc.); however, only awards with mechatronics as the primary topic were listed.

Table 4 - National Science Foundation Grants for Mechatronics Since 1992

Award#	NSF Grant Title	Awarded to Date	Start Date
9213542	Engineering Faculty Internship: Mechatronic Design & Constr. of a Materials Handling Test Apparatus	$24,208	15-Jun-92
9300025	A Design Information System for Concurrent Engineering with Application to Mechatronics Design	$238,311	1-Jul-93
9352301	Design Of Mechatronic Systems	$93,911	1-Jul-93
9354913	Mechatronics in Machine Tool Research. (Focus Area-Machine Tool Research)	$557,500	1-Oct-93
9354403	Design of Electro-Mechanical (Mechatronic) Systems An Integrated Inter-Departmental Curriculum	$110,000	1-Jun-94
9414585	Integrated Structure/Control Design of Mechatronic Systems Using a Recursive Structure Reinforcement Method	$225,000	1-Oct-94
9455124	Preparing Leaders for Mechatronics Education	$150,000	1-Jan-95
9455395	Undergraduate Curriculum Development on Mechatronic Systems Engineering	$494,279	1-Feb-95
9513162	East Asia & Pacific Regional Workshop: Mechatronics Technology in San Jose, CA, May 19-24, 1996	$49,957	1-Mar-96
9622220	REG: Development of a Mechatronics Workstation	$42,266	1-Aug-96
9651083	The Mechatronics Design Workshop	$41,000	15-Aug-96
9632828	Mechatronic Design and Control of Media Handling Mechanisms for Printing Engines	$197,426	15-Sep-96
9634796	Control Theory for Nonlinear, Distributed, Mechatronic Systems with Applications	$63,834	1-Jan-97
9652937	Learning by Tinkering: Applications of a PC Printer Port in Mechatronics	$120,000	1-Mar-97
9706642	International Conference on Advanced Intelligent Mechatronics; Waseda University, Tokyo, Japan; June 16-20, 1997	$26,000	1-Mar-97
9619992	Research Experience for Undergraduates in Mechatronics and Smart Structures	$238,441	1-Apr-97
9751387	Development of a New Multidisciplinary Undergraduate Mechatronics Laboratory	$64,196	1-Jul-97
9722870	Mechatronic Design Course and Japan Site Visits	$15,660	1-Aug-97
9750672	Mechatronics Experiments in Mechanical Engineering Laboratory	$57,815	1-Aug-97

Award#	NSF Grant Title	Awarded to Date	Start Date
9751050	Undergraduate Mechatronics Laboratory	$86,583	1-Aug-97
9820071	US-Turkey Workshop: Recent Advances in Mechatronics, Istanbul, Turkey, May 24-26, 1999	$12,000	1-Mar-99
9950782	Development of a Remote Access Internet Based Mechatronics/Process Control Laboratory	$99,998	1-Jul-99
9950862	Mechatronics: A Comprehensive Interdisciplinary Curriculum Development	$90,000	1-Jul-99
9906233	US-Turkey Cooperative Research: Application of VLSI Based Soft Computing to Mechatronics	$35,000	1-Aug-99
9952301	Development of a Mechatronics and Intelligent Machines Laboratory	$31,000	15-Feb-00
1455	Mechatronics Education Workshop	$25,000	15-Aug-00
84934	Automated Design of Mechatronic Systems Using Bond Graphs and Genetic Programming	$308,698	15-Aug-00
196045	US-Turkey Cooperative Research: Application of VLSI Based Soft Computing to Mechatronics	$29,500	8-Nov-00
93312	CAREER: Multi-task-domain Distributed Manipulation and Mechatronics Education	$336,513	15-Mar-01
93744	CAREER: A Mechatronic Framework for Magnetic Suspension Technology	$375,000	1-Jun-01
126966	Microcontroller/Mechatronics Education of Non-Electrical Engineering Students	$71,000	15-Jan-02
139117	REU: Summer Research Experiences for Undergraduates in Micro Mechatronic Systems	$366,199	1-Mar-02
126709	A Multidisciplinary Control Laboratory	$63,000	1-May-02
230544	Converging Technologies: The New Frontier in Engineering Education	$100,000	1-Oct-02
227479	Research Experience for Teachers Site in Mechatronics	$450,000	1-Jan-03
336439	Partial Travel Support for US Researchers to Attend 2003 IEEE/ASME Advanced Intelligent Mechatronics Conference (AIM03)	$10,000	15-Jul-03
309719	New Course Development in Advanced Mechatronics	$174,192	15-Sep-03
352771	U.S.-Turkey Cooperative Research: Silicon Implementation of Computational Intelligence for Mechatronics	$37,000	15-May-04
423288	U.S-Turkey Workshop on "Mechatronics, Control & Automation", Istanbul & Kusadasi, Turkey, June 2004	$22,867	1-Jul-04
428917	SST: Control-oriented Optimal Multisensor Design and Microfabrication for Structural Vibration	$380,001	1-Aug-04

Award#	NSF Grant Title	Awarded to Date	Start Date
	Suppression in Mechatronic Systems (GOALI)		
423739	RR:CISE Instrumentation: Remote Research Capability with Hardware-in-the-loop Simulators for Mechatronic Systems	$49,866	15-Aug-04
443484	Travel Support for US Attendees at the Third International Federation of Automatic Control (IFAC) Symposium on Mechatronic Systems	$5,000	1-Sep-04
451274	US-Japan Cooperative Program on Sensors, Smart Structures, and Mechatronic Systems	$150,000	15-Sep-04
520155	Partial Student Travel Support for US Students to Attend 2005 IEEE/ASME Advanced Intelligent Mechatronics Conference (AIM'05); Monterey, CA; July 24-28, 2005	$5,000	1-Jul-05
531531	Joint U.S.-China Workshop on Integrated Sensing Systems, Mechatronics and Smart Structures Technologies; September 19-21, 2005; Shandong Province, China	$30,560	1-Jul-05
529451	Sensors: Sensing Rich Drive Trains for Modern Mechatronic Systems	$290,001	15-Aug-05
	Total Mechatronic Awards	**$6,443,782**	

Student Demand for a Mechatronics Engineering Degree

Since inception in 2003, SPSU has formed and operated the Georgia Boosting Engineering, Science, and Technology (BEST) Robotics K-12 outreach program. Corporate sponsors and many dedicated individuals from industry and academia have volunteered each year to support the Georgia BEST robotic competitions. Southern Polytechnic has been the host venue for the 2003, 2004, & 2005 State of Georgia competitions.

The BEST competition motivates students by challenging them to build a remotely controlled robot that accomplishes a defined task within a competitive setting. A professional engineer and a school coach guide student teams through the engineering process. Using only the materials provided, students have six weeks to design, develop, and test a robot that can outperform their competitors. During this time, the students experience the same problems, challenges, and breakthroughs that an engineering team encounters when it takes a product to market. In all cases, there are team dynamics, time constraints, material constraints, and pressure from other teams who are trying to solve the same problem. Placed in a real situation, with real problems, the students provide real (and ingenious) solutions.

In the 3 years of operation, the number of participating schools has doubled, beginning with 12 high schools in 2003. In 2005, 24 high school and middle school teams from across the state competed; drawing about 1,500 students, parents, and supporters to the event. In the near future, additional venues will have to be added because the SPSU facility is near capacity for the size of the competition. The rapid growth of the Georgia BEST Robotics competition leads to the conclusion that there is significant high school student interest in robotics. Robotics is one of the primary applications of mechatronic principles.

Figure 2 shows the number of high school students across the U.S that competed in the BEST Robotics Competition for the last 9 years. The number of BEST competitors has continually increased since its inception.

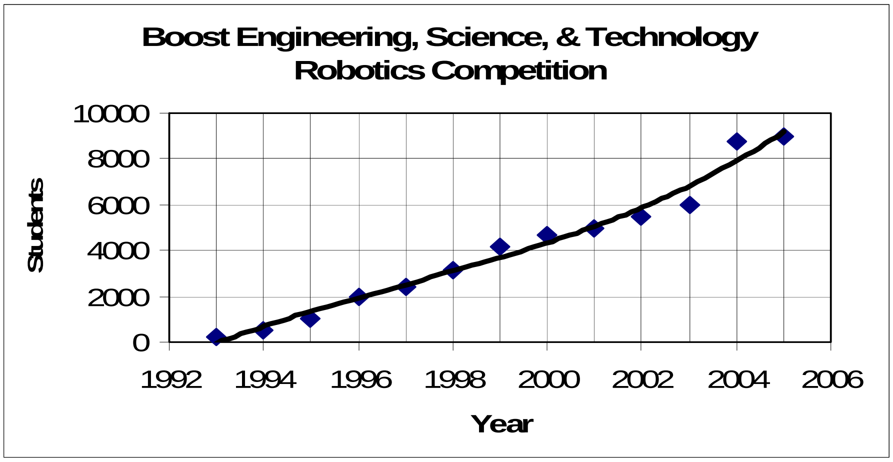


Figure 2 - BEST Robotics Competition Student Growth

SPSU is also a regional sponsor for the FIRST (For Inspiration and Recognition of Science and Technology) Robotics Competition. FIRST has grown to more than 25,000 high school students in its annual national competition. As shown in Figure 3, high school student interest in FIRST robotics continues to show significant growth.

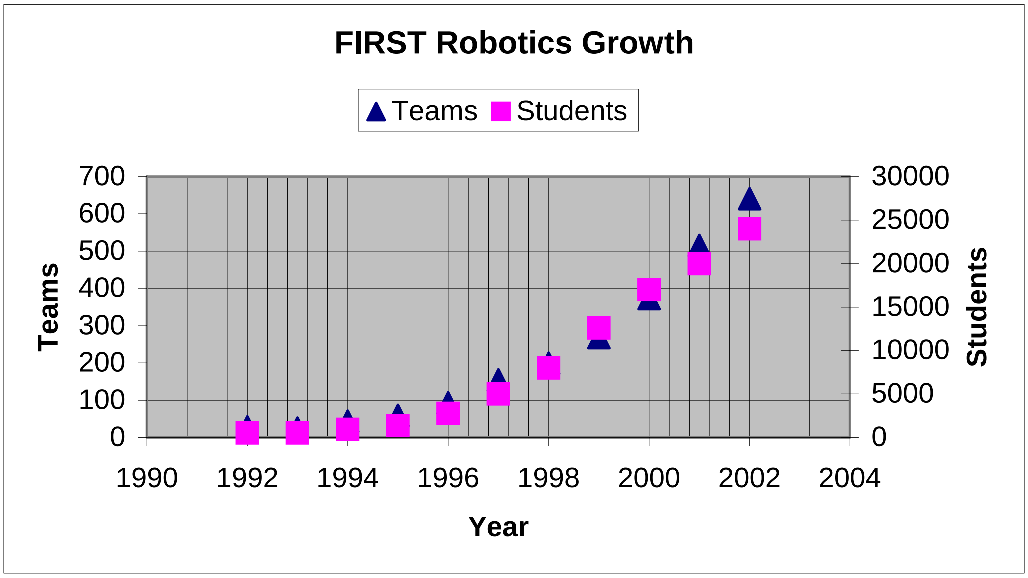


Figure 3 - First Robotics Competition Student Growth

Both the BEST and FIRST competitions are sponsored by companies(notably Siemens, NASA, Lockheed, Scientific Atlanta, etc.) that want to foster students' interest in general engineering and mechatronics in particular.

B.S. in Mechatronics Engineering Curriculum

The B.S. Mechatronics Engineering degree proposed by Southern Polytechnic is designed to be 128 hours. The program will consist of the University System of Georgia (USG) Core curriculum, the Electrical Engineering Core, the Mechanical Engineering Core, Software Engineering, and Mechatronics Engineering. The mechatronics program hours by component are as follows:

- USG Core Curriculum – 60 credit hours
    - Area A – Essential Skills – 9 Hours
        - Composition I – 3 Hours
        - Composition II – 3 Hours
        - Calculus I – 4 Hours (1 extra hour carried over to Area F)
    - Area B – Institutional Options – 4 Hours
        - Public Speaking – 2 Hours
        - Science, Technology, and Society – 2 Hours
    - Area C – Humanities / Fine Arts – 6 Hours
        - Literature of the World – 3 Hours (Any One)
            - World Literature – 3 Hours
            - Western Literature I – 3 Hours
            - Western Literature II – 3 Hours
            - British Literature – 3 Hours
            - American Literature – 3 Hours

        - Art and Culture of the World – 3 Hours (Any One)
            - Art Appreciation – 3 Hours
            - Drama Appreciation – 3 Hours
            - Music Appreciation – 3 Hours
            - Elementary French II – 3 Hours
            - Elementary German II – 3 Hours
            - Elementary Spanish II – 3 Hours
    - Area D – Science, Mathematics, and Technology – 11 Hours
        - Principles of Physics I – 4 Hours
        - Principles of Physics II – 4 Hours
        - Discrete Mathematics – 3 Hours
    - Area E – Social Sciences – 12 Hours
        - American Context – 3 Hours (Any One)
            - U.S. History I – 3 Hours
            - U.S. History II – 3 Hours
            - American Government – 3 Hours
        - World History – 3 Hours (Any One)
            - World Civilization: Ancient – 3 Hours
            - World Civilization: Medieval – 3 Hours
            - World Civilization: Modern – 3 Hours
        - Behavioral Sciences – 3 Hours (Any One)
            - Introduction to Economics – 3 Hours
            - Introduction to General Psychology – 3 Hours
        - Culture & Societies – 3 Hours (Any One)
            - Introduction to Anthropology – 3 Hours
            - Ethnic Studies – 3 Hours
            - Introduction to Human Geography – 3 Hours
            - Global Issues – 3 Hours
            - World Religion – 3 Hours
    - Area F – Related to Major of Study – 18 Hours
        - Principles of Chemistry I – 4 Hours
        - Technical Writing – 3 Hours
        - Ordinary Differential Equations – 3 Hours
        - Probability & Statistics – 3 Hours
        - Calculus II – 4 Hours
        - Core Area A Carry Over of 1 Hour
- Mechanical Engineering Courses – 23 Hours
    - Survey of Engineering Graphics – 2 Hours
    - Statics – 3 Hours
    - Dynamics – 3 Hours
    - Strength of Materials & Engineering Materials – 4 Hours
    - Fluid Mechanics – 4 Hours
    - Machine Dynamics for Mechatronics Engineers – 3 Hours
    - Instruments and Controls – 4 Hours

- Electrical Engineering Courses – 20 Hours
    - Circuits – 4 Hours
    - Digital Circuits – 4 Hours
    - Electronics I – 4 Hours
    - Electric Machines – 4 Hours
    - Control Systems – 4 Hours
- Software Engineering Courses – 8 Hours
    - Software Engineering I – 4 Hours
    - Software Engineering II – 4 Hours
- Mechatronics Engineering Courses – 14 Hours
    - Survey of Mechatronics Engineering – 1 Hour
    - Mechatronics Engineering Fundamentals – 3 Hours
    - Robotics Analysis and Synthesis – 3 Hours
    - Digital Controls for Mechatronics Engineering – 3 Hours
    - Mechatronics System Design – 4 Hours

The Mechatronics Engineering curriculum is shown graphically in

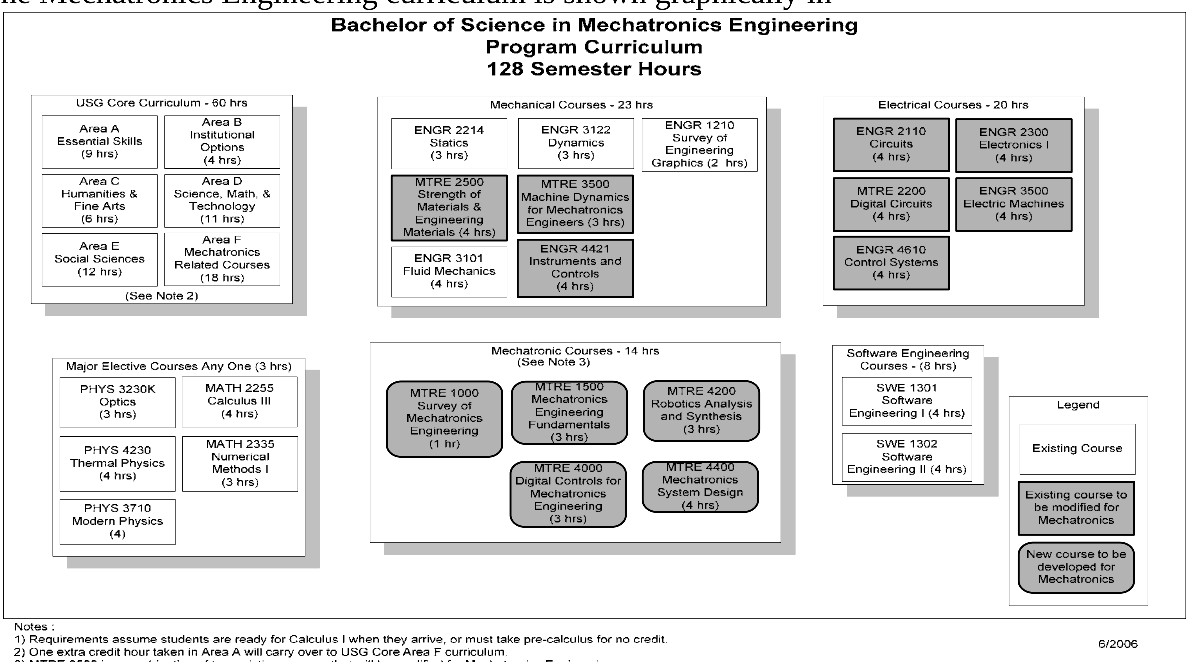
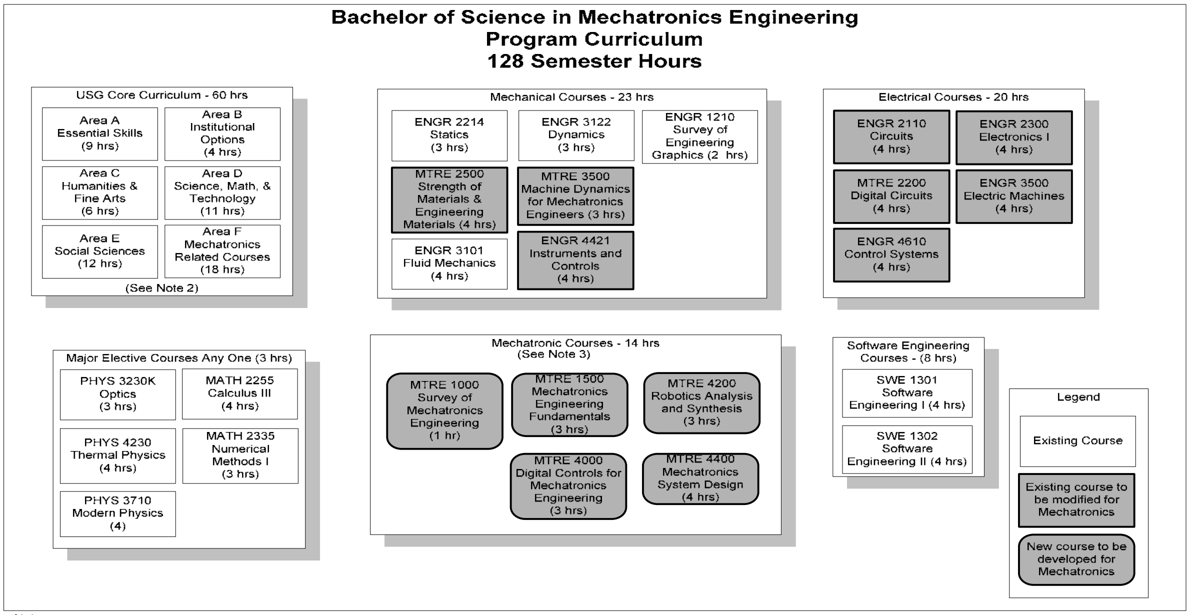


Figure 4. The core curriculum courses are detailed in

Figure 5 and the course sequences are illustrated in the curriculum flowchart provided in Figure 6. The program delivery format at SPSU will be focused on applied engineering; providing a mixture of lecture and laboratory.



Notes :
1) Requirements assume students are ready for Calculus I when they arrive, or must take pre-calculus for no credit.
2) One extra credit hour taken in Area A will carry over to USG Core Area F curriculum.
3) MTRE 2500 is a combination of two existing courses that will be modified for Mechatronics Engineering.

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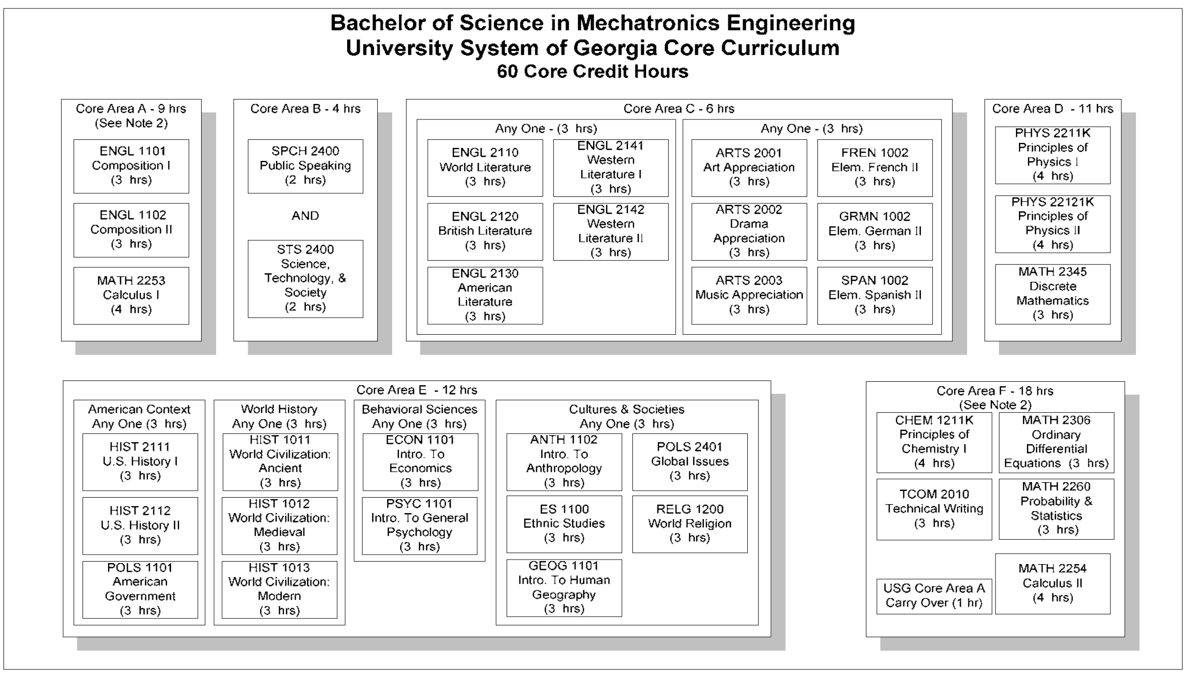
Figure 4 - Bachelor of Science Mechatronics Engineering Curriculum Diagram



Notes :
1) Requirements assume students are ready for Calculus I when they arrive, or must take pre-calculus for no credit.
2) One extra credit hour taken in Area A will carry over to USG Core Area F curriculum.

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Figure 5 - Bachelor of Science Mechatronics Engineering Core Curriculum

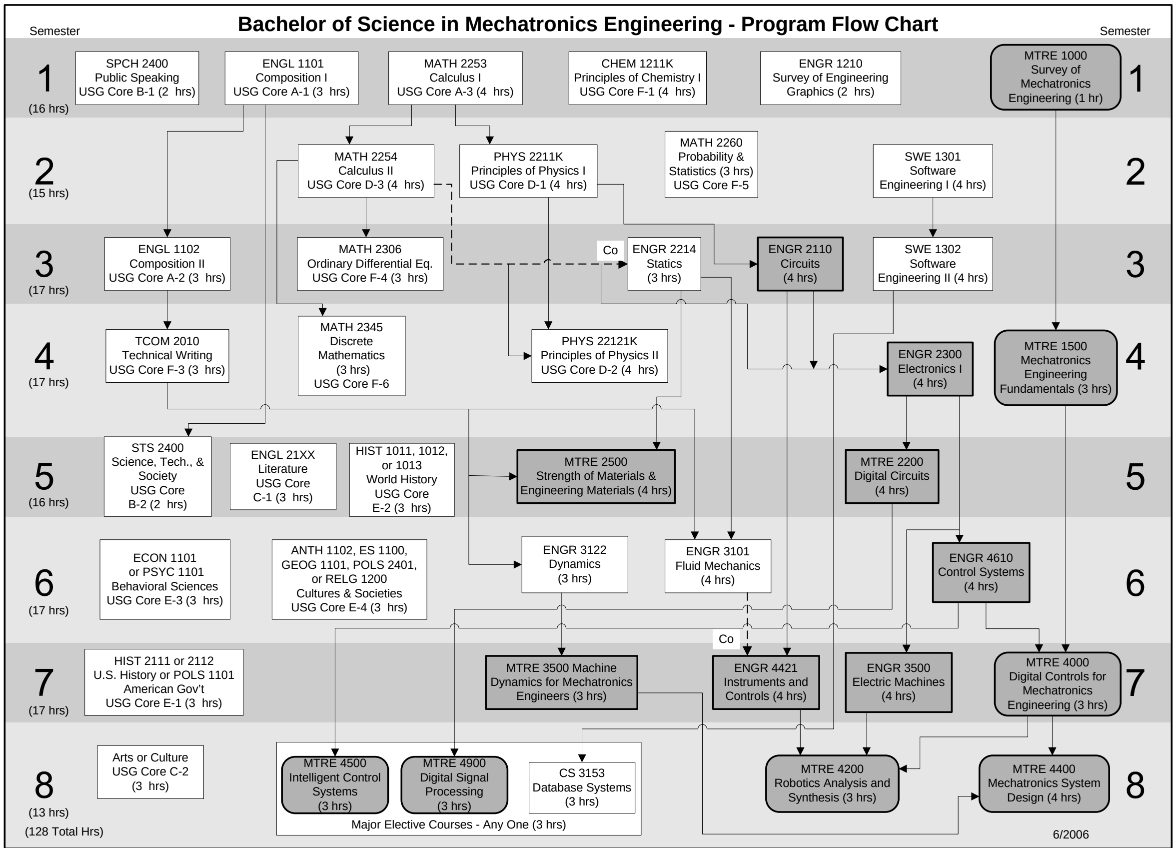

Figure 6 - Bachelor of Science in Mechatronics Engineering Program Flow Chart

Conclusions

As evidenced by the continued growth in the FIRST and BEST robotics competitions, a clear conclusion can be made that high school students have a great interest in mechanisms and electronics (Mechatronics) and that interest is showing a significant increase. In an impact study, FIRST Robotics concluded that competition students are more than three times as likely to major specifically in engineering as compared to non-competing students [29].

The lack of interdisciplinary education and its importance are documented [11]. Higher education in the United States is not keeping pace with the rest of the world in offering interdisciplinary degrees in mechatronics. Mechatronics has been evolving in industry and education since its definition in 1969 and is now widely recognized around the world. There are forty-two undergraduate Mechatronics Engineering Programs recognized by the Accreditation Board of Engineering and Technology (ABET) / Engineering Accreditation Commission (EAC). These programs are offered in 7 countries. However, only one of the 42 degree programs is from a university in the United States. While many may acknowledge the importance of interdisciplinary education and specifically mechatronics engineering, it is apparent with only one accredited program, the U.S. higher education system has been slow to develop programs compared with other parts of the world.

There is a critical shortage of students enrolled in Science and Engineering fields. The trend is significant to the point where the economic welfare and security of the United States is threatened [19]. To counter this trend, universities need to create interdisciplinary programs that will attract students and also meet the work force requirements of industry.

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