

Master of Science Program in Mechatronics

Proposed Start Date: Fall 2010

Submitted jointly by

**Department of Electrical and Computer Engineering and
Department of Mechanical Engineering**

**School of Engineering and Computer Science
Oakland University**

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SUMMARY

A new Master of Science degree program in Mechatronics is proposed. The need for such a program arises from the fact that Mechatronics is a very important multi-disciplinary engineering specialty needed in its ever-growing applications in consumer products, manufacturing, transportation systems, security systems, defense systems, aerospace, sports engineering, biomedical systems, etc. It is ubiquitous in automotive systems and therefore is a very important engineering discipline for the state of Michigan.

Mechatronics is generally recognized worldwide as a vibrant, emerging area of study. Both undergraduate and graduate degree programs in mechatronics are now offered in many universities in USA and abroad. In Michigan, Lawrence Technological University is the only institution currently offering such a program, but a number of other local institutions are currently considering such offerings.

The proposed Master's program in Mechatronics is consistent with the role and mission of Oakland University. It will provide excellent instruction in a focused discipline, and serve the need for mechatronics engineers for automotive, robotics, defense, and biomedical engineering companies. Thus, it is highly relevant for both existing as well as emerging industries in Michigan. Also, its academic and industrial flavor has the potential to attract out-of-state and international students to the program. The proposed program is also expected to provide some public and community service to the region and the state of Michigan.

The proposed program is unanimously supported by the faculty of the departments of Electrical and Computer Engineering (ECE), and Mechanical Engineering (ME). These two departments have well known research centers as well as a number of well equipped laboratories, which are used everyday for state-of-the-art research and instruction in various areas of ECE and ME. Also, both departments currently offer a wide range of courses for graduate students.

The ECE Dept has established an Automotive Mechatronics Lab and Rapid-Prototyping Embedded Control Lab since 1997 with funding support from the NSF, Ford Motor Co., Hitachi America, General Dynamics Land Systems, and private donor Lou & Carol Ross. Mechatronics courses such as ECE 4/575 and ECE 4/572 have been taught every year since then, with full enrollment each semester. The courses involve extensive hands-on lab experiments, projects and computer-aided engineering software experience.

For admission to the proposed Master's program in Mechatronics, normally a bachelor's degree with a GPA of at least 3.0 in electrical engineering, computer engineering, mechanical engineering or systems engineering will be required. To earn a M.S. degree in Mechatronics, a student must complete at least 32 credits of relevant coursework beyond the bachelor's degree.

Finally, the proposed program is envisaged to be a multi-disciplinary engineering program based mostly on the existing courses offered by the four departments of the School of Engineering and Computer Science. As a result, very little new resources will be needed to launch this program. Specifically, the only new resources include two part-time faculty positions and two additional teaching assistantships per year. We are very hopeful that the proposed program will increase our graduate enrollment, and generate additional revenue for the university

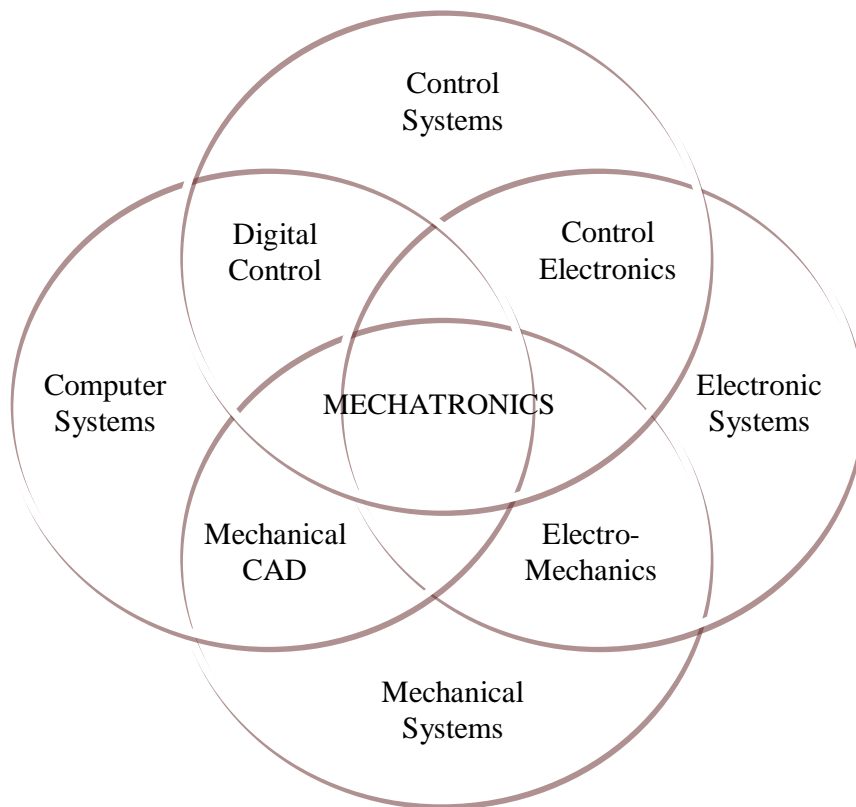
without requiring new resources. Based on a conservative budget estimate, the program is expected to be almost self-sufficient from the first year, and generate additional net income for the university from second year onward.

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1. Background

Mechatronics is a synergistic hybrid field of mechanical engineering, electronic engineering, computer engineering and control engineering. Figure 1 illustrates a typical overlap of the multi-disciplines. Mechatronics is centered on mechanics, electronics, control, software computing, embedded processing, communications, electromagnetism, electro-mechanism, micro- and nano-technologies. The synergy leads to generation of simpler, more economical, reliable and versatile systems.



Despite continuing efforts to define mecha-tronics, to classify mechatronic products, and to develop a standard mechatronics curriculum, a consensus opinion on an all-encompassing description of “what is mechatronics” eludes us. This lack of consensus is a healthy sign. It says that the field is alive, that it is a youthful subject. Engineers understand the essence of the philosophy of mechatronics from their own personal experiences. An informative definition follows: *Mechatronics is a systems engineering process for development and integration of computer-based electronically controlled mechanical components in a timely and cost-effective manner into smart affordable quality products that ensure optimum, flexible, reliable and robust performance under various operating and environmental conditions.* We refer to such a well-designed and well-integrated automation system as a mechatronic system or product.

2. Need for the program

Mechatronic systems are found in consumer products (entertainment, home, office, stores), manufacturing (machine tools, robot manipulators, assembly lines), transportation systems (traffic information and control), security systems (police robots, nonlethal devices), defense systems (machines and vehicles), exploratory systems (unmanned vehicles and sensors), aerospace, sports engineering, medical systems, etc. Mechatronics is ubiquitous in automotive systems; they include luxury/convenient options such as the control of power windows, seats, mirrors, wipers, trunk, roof, climate, etc.; performance improvement for engine, transmission, emission, knock suppression; dynamic enhancements such as anti-lock braking system (ABS), automatic speech recognition (ASR), electronic stability program (ESP), active suspension; safety aids such as collision avoidance, intelligent cruise, anti-rollover, lane departure detection; integration of entertainment and communications; and many others.

For many practicing engineers, mechatronics is nothing new. Many engineering products of the last 30 years are integrated mechanical, electrical, and computer systems, designed by engineers that were never formally trained in mechatronics per se. Modern concurrent engineering design practices are natural design processes, now viewed as a part of the mechatronics.

The study of mechatronics provides a means for scholars interested in understanding and explaining the engineering design process to define, classify, organize, and integrate many aspects of product design into a coherent package. As the traditional boundaries among various engineering disciplines tend to become less apparent, we should take comfort in the existence of mechatronics as a field of study in academia that bridges the historical divisions of mechanical, electrical, aerospace, chemical, civil, and computer engineering. The mechatronics specialty provides an educational roadmap for engineering students studying within the traditional structure of most engineering colleges.

Mechatronics is generally recognized worldwide as a vibrant area of study. Undergraduate and graduate programs in mechatronic engineering are now offered in many universities. Refereed journals are being published and dedicated conferences are being organized and are generally highly attended.

It should be understood that mechatronics is not just a convenient structure for investigative studies by academicians; it is a way of life in modern engineering practice. The introduction of the microprocessor in the early 1980s and the ever increasing desired performance to cost ratio revolutionized the paradigm of engineering design. The number of new products being developed at the intersection of traditional disciplines of engineering, computer science, and the natural sciences is ever increasing. New developments in these traditional disciplines are being absorbed into mechatronics design at an ever increasing pace. The ongoing information technology revolution, advances in wireless communication, smart sensors design (enabled by MEMS technology), and embedded systems engineering ensures that the engineering design paradigm will continue to evolve in the early twenty-first century.

The proposed Master's program in Mechatronics will serve the need for mechatronics engineers for automotive, robotics, defense, and biomedical engineering companies. It is highly relevant for the industries in Michigan. Also, its academic and industrial context has the potential to attract out-of-state and international students to the program.

3. How the Program Will Help Promote the Role and Mission of the University

The role and mission of Oakland University (OU) identifies four essential ingredients: excellent and relevant instruction, high-quality basic and applied research and scholarship, responsive and effective public and community service and a comprehensive schedule of student development activities.

The proposed Master's program in mechatronics is consistent with the role and mission of the university. It offers a unique multidisciplinary graduate education consisting of pertinent courses from the disciplines of Electrical Engineering (EE), Computer Engineering (CE), Mechanical Engineering (ME) and Systems Engineering (SE). The program is designed to appeal to students with different engineering backgrounds, experience and goals by offering some flexibility in their selection of coursework. It is meant to appeal to students who desire to widen their technical knowledge in mechatronics, as well as those who wish to pursue advanced research in the field of mechatronics.

Students electing a study, project or thesis as part of their coursework will be encouraged to investigate mechatronics problems relevant to science, technology and society needs. These may involve semiautonomous robotics and unmanned vehicle systems that are presently heavily emphasized in the military and defense sectors. They can be various forms of subsystems in hybrid or plug-in electric vehicles, new automobile features, and automation and manufacturing technologies important to the recovering Michigan automotive industry. Necessity will lead to innovative ideas for mechatronics devices that add value to the society in general. The ECE and ME Departments have already begun to work with the School of Nursing and new OU William Beaumont School of Medicine to identify projects that faculty and students can collaborate on. Collaborative effort with local industries will emphasize present and future role of mechatronics systems, and help to refine the proposed MS program.

The departments are working to establish a Research Experience for Undergraduates (REU) program in Mechatronics. As a service to the public and community, the ECE department has been organizing and hosting the Annual Intelligent Ground Vehicle Competitions at OU for the past 17 years. Future endeavors will include exhibiting Mechatronics projects to the participants of Detroit Area Pre-College Engineering Program (DAPCEP) to allure them toward engineering, organizing seminars/workshops/conferences in Mechatronics, and providing workforce retraining programs for displaced technical workers.

The Mechatronics program will exemplify Oakland University's educational leadership through fulfilling the needs in southeastern Michigan and the Midwest region.

4. Goals of the Program

Overall, the goals of the program are:

- (a) To attract more graduate students to Oakland University by diversifying our curricular offerings,
- (b) To offer our graduate students an opportunity to specialize in emerging technological areas,
- (c) To enhance the breadth of our graduate course offerings, and
- (d) To enhance our visibility nationally and globally.

The proposed program will provide a graduate-level in-depth learning experience in the topics of mechatronics. Students will learn multi-level, multi-disciplinary, mixed-mode and multi-organizational engineering nature of mechatronic systems. They will use computer-aided engineering tools and apply analysis and design principles of mechatronic systems. Practical applications and recent technologies will be emphasized.

As an added benefit, Oakland University will join a select group of colleges that offer a full-fledged degree program in mechatronics. This will enhance our visibility both nationally and globally.

5. Comparison to Similar Programs in Michigan

There is only one similar program in Michigan, namely, Master of Science in Mechatronic Systems Engineering, offered by Lawrence Technological University, Southfield, MI. This was introduced about a year ago.

There is an elective course, ECE 585 (Mechatronics), offered at Western Michigan University by the Electrical and Computer Engineering Department. A similar course, AE 512 (Mechatronics in automotive applications), is offered by University of Michigan at Dearborn. Also, there is a Controls and Mechatronics Research Laboratory at Michigan State University. We are also aware of the fact that a number of local colleges and universities are considering the possibility of offering Mechatronics programs in their campuses.

6. Source of Students

Due to its multidisciplinary character, mechatronics includes more knowledge fields needed for auto industry than any other engineering subjects. Located at the center of the world's capital of automotive industry, Oakland University is surrounded by hundreds of auto related companies and research institutes. Undoubtedly the new Master's program in Mechatronics will attract local, national and even international students who have earned their bachelor degrees and have ambition to join automotive industry and research. In addition, the employees of local industries, who are motivated to pursue state-of-the-art technologies, will be another main source of students for the new program. Moreover, since Mechatronics has promising applications in micro-electromechanical systems (MEMS), nano-electromechanical systems (NEMS) and

biological engineering, the new program will also attract students who are prepared to take a career in biomedical, pharmaceutical and other fast-growing industries, which are in line with the new orientation of Michigan's economy.

7. Relationship to Existing Graduate Programs in SECS

The Electrical and Computer Engineering (ECE) department has successfully offered a course called Automotive Mechatronics, EE 475/575 and SYS 475/575, every winter semester since 1997. It is a lab and project oriented course. The lab equipment is supported by an external funding from Ford University Research Program (URP) and Hitachi-America. The enrollment in each semester is about 20 students, capped by the department. After discussion with industry representatives and SECS engineering advisory boards, the ECE Department decided that it is meaningful to introduce the Master of Science program in Mechatronics at this time.

The proposed Master's Program in Mechatronics is envisaged to be a multi-disciplinary engineering program based mostly on the existing courses offered by the four departments of the School of Engineering and Computer Science (SECS). It will be administered jointly by the departments of ECE and Mechanical Engineering (ME).

The School of Engineering and Computer Science (SECS) currently offers programs leading to the Ph.D. degree in mechanical engineering, systems engineering, and computer science and informatics and the Master of Science degree in electrical and computer engineering, industrial and systems engineering, mechanical engineering, systems engineering, computer science, embedded systems, and software engineering and information technology. It also offers a Master of Science program in engineering management in cooperation with the School of Business Administration.

The proposed Master of Science program in Mechatronics is not in conflict with any of the above programs, because it is a multi-disciplinary program. In fact, because of its multi-disciplinary nature, it is expected boost enrollments in many courses offered by the different departments of SECS.

8. Goals of the Unit Served by the Program

A current goal of the ECE and ME departments is to increase both the quality and diversity of our curricular offerings. The proposed program will support this goal by creating an opportunity for our graduate students to pursue a Master's program in an emerging technological area, producing an influx of new graduate students, increasing research activities in areas related to mechatronics, generating additional technical publications and development of new courses. Another goal is to increase research collaboration with local industries. The new program will accomplish this by allowing engineers working in local industries to pursue a Master's degree in Mechatronics with enthusiastic support of their employers, and it is expected that many students will undertake mechatronics graduate projects supported by local industries.

9. Faculty Qualifications and Departmental Strengths

Electrical and Computer Engineering Department

The ECE faculty are actively engaged in research in various areas of Electrical and Computer Engineering, and most of them have external research supports from either government funding agencies or local industries. Some of the departmental strengths as demonstrated by the faculty research areas are highlighted below.

Hoda S. Abdel-Aty-Zohdy: Bio-Technology with Bio-Inspired Intelligent Signal Perception and Processing (ISPP); Electronic Nose and other bio-inspired systems including smart interface-systems and novel resonating polymer-sensors; Sub-micro-electronics, VLSI circuits of embedded neural networks and genetic algorithms for novel systems-on-a-chip; Analog, Digital and Mixed-Signal Integrated Circuits; Device/circuit modeling and simulation; 3-D Electronic Devices: low noise, low power.

Daniel N. Aloï: Electromagnetics; Antenna design; All aspects of Global Positioning Systems (GPS).

Ka C. Cheok: Control and estimation theory: optimal, adaptive, robust, fuzzy, neural, intelligent systems; Mechatronics: modeling, simulation, computer tools, virtual prototyping, rapid hardware prototyping, systems engineering; Semi-autonomous and intelligent systems: unmanned ground robotics, computer vision, navigation and guidance, human-machine interface.

Manohar Das: Adaptive signal processing; System identification and adaptive control theory; Digital signal processing; Digital image processing; Data compression; Pattern recognition; Modeling and simulation; Monitoring and adaptive control of resistance spot welding process.

Pieter A. Frick: Real time computer systems; Optimization and optimal control; Parallel computing in systems and control; Power system modeling and control; Stochastic processes; System identification.

Subramaniam Ganesan:

Multiprocessor Architecture, Real Time Multiprocessor Systems for Specific Applications, DSP Processor Based Systems

Edward Y. Gu: Kinematics, task-planning, dynamic modeling and control of robotic systems; Modeling, analysis, adaptive control and computer simulations of nonlinear systems; Human biomechanical and biodynamic modeling and digital simulations; Learning and intelligent control of Human-Machine Interactive Systems.

Darrin Hanna:

Mixed-mode microprocessor-less systems such as FPGAs, ASICs, and MEMS with Artificial Intelligence for Bio-MEMS and other embedded systems. Includes high speed, low power processing systems for sensors and actuators using FPGAs.

Richard E. Haskell: Pattern Recognition; Soft computing; Embedded systems; Computer learning; Microprocessor applications.

Jia Li: Automatic segmentation of 3D Ultrasonography for Fetal Growth Analysis; Tumor dose quantification using I-131 SPECT; Quantitative assessment of Gestational Sac Shape; Channel Sounding for ultra-wideband intra-vehicle communications; Prototyping intra-vehicle wireless sensor networks.

Robert N.K. Loh: Control systems, estimation theory, systems identification; Robotics, intelligent systems, complex autonomous systems, unmanned ground vehicles, unmanned underwater vehicles, unmanned aerial vehicles; Automotive systems, advanced defense systems, digital signal and image processing, and time series analysis.

Hongwei Qu: Micro-electro-mechanical systems (MEMS); CMOS-MEMS technology; CMOS-MEMS inertial sensors; Physiological and security monitoring using CMOSMEMS devices; Nanotechnology and devices; MEMS/NEMS modeling.

Osamah A. Rawashdeh: Embedded Systems; Fault tolerance; Instrumentation; Ubiquitous computing.

Andrzej Rusek: Electromagnetic compatibility; Cell phone interference; Testing and modeling of automotive data busses.

Mohamed A. Zohdy: Advanced control and estimation; Intelligent pattern information processing; Neural, fuzzy, and evolutionary systems; Chaos control; Smart simulation and hybrid systems; Fuel Cell modeling and control for transportation; Micromotor analysis with applications to biomedical engineering; Control of biological regulatory networks.

Mechanical Engineering Department

The ME faculty are actively engaged in research in various areas of Mechanical Engineering, and most of them have external research supports from either government funding agencies or local industries. Some of the departmental strengths as demonstrated by the faculty research areas are highlighted below.

Gary Barber: Tribology of Engine Cylinder Kits, Engine Valve Wear, Effect of Tool Wear on the Surface Topography of Machined Surfaces, Vibratory Stress Relief

Yin-ping (Daniel) Chang: FEA tire modeling and dynamics simulations, Vehicle modeling and dynamics simulations, Vehicle passenger safety systems modeling and

simulations, Contact-impact problems experiments and simulations, Machine/mechanism synthesis and analysis.

Randy J. Gu: Finite Element Applications, Mechanical Computer-Aided Engineering, Experimental/Theoretical Studies of Contact Problems, Material Behavior Modeling, Inverse Problems.

Laila Guessous: Simulation and modeling of turbulent pulsating flows; Turbulence Computational Fluid Dynamics (CFD) and parallel computing; Shape optimization Natural convection; Heat transfer correlation development.

Michael Y.Y. Hung: Nondestructive Testing and Material Evaluation, Design Validation and Optimization, Experimental Stress Analysis, Vibration and Noise Analysis, Optical Measurement and Quality Inspection, Full-field Dimension Gauging and Coordinate Measurement, Microelectronic Reliability.

Ching L. Ko: Mechanics of Composite Materials and Structural Design, Finite-Element Analysis of the Metal-Forming Process, Computational Fluid Mechanics and Numerical Heat-Transfer Analysis, Vibration Analysis of Plate and Shell Structures, Hot-wire and LDA Measurements in Fluid Flows, Analytical Modeling of Fluid-Structure Interaction Dynamics and Nonlinear Vibration, Impact Dynamics and Plasticity.

Michael A. Latcha: Modeling and Simulation of Multi-Body Systems, Numerical Acoustics, Machine Design.

Keyu Li: Optical Techniques for Measurements of Strains and Stresses; Smart Materials to Measure Permanent Deformations and Residual Stresses Induced from Manufacturing Processes; Material Evaluation and Characterization; FEM Modeling of Material Behavior and Structural Mechanics; FEM Simulation of Manufacturing Processes such as Quenching; Noncontacting Methods for Dynamic and Vibration Measurement; Fatigue, Creep and Fracture Mechanics; Tribology Modeling.

Zissimos P. Mourelatos: Design under Uncertainty (Probabilistic Design); Reliability - Based Design Optimization (RBDO); Reliability Analysis with Insufficient Data (Lack of Information); Multi-disciplinary Design Optimization (MDO) under Uncertainty; Efficient Sampling and Response Surface Generation; Noise, Vibration and Harshness (NVH); Internal Combustion Engine Dynamics: Crankshaft - Block Dynamic Interaction through Elastohydrodynamic Main Bearings, and Elastohydrodynamic Piston - Cylinder Bore Interaction; Coupled Internal Combustion Engine Dynamics and Heat Transfer; Dynamic Substructuring of Large - Scale, Complex Structures; Elastohydrodynamic (EHD) Bearing Lubrication.

Sayed Nassar: Mechanical fastening and adhesive bonding of composite joints, use of ultrasonics to control bolt tightening, clamp load loss, optical inspection and control of bolted joints, self loosening of threaded fasteners, tribological and contact mechanics simulation of bolted joints, and non-linear finite element modeling of bolted joints.

Brian P. Sangeorzan: Droplet and Particle Sizing Methods; Fuel Sprays and Liquid Atomization; Heat Transfer and Fluid Mechanics; Internal Combustion Engines; Instrumentation and Optical Diagnostic Techniques related to above; High-speed motion photography.

Lorenzo M. Smith: Failure Criteria; Springback Modeling; Manufacturing Processes; Finite Element Formulations; Experimental Mechanics.

Xia Wang: Turbulent Boundary Layers with Separation; Forced Convection Turbulent Boundary Layers; Equilibrium and Non-equilibrium Turbulent; Boundary Layers; Turbulent Boundary Layers Control; Scaling Laws in Bio-Fluid; Biothermal; Modeling in Micro-channel heat transfer.

LianXiang Yang: Digital optical measuring techniques for full-field, non-contacting; Three dimension measurement of contour, deformations and strains/stresses etc.; Digital image processing and new software development; Experimental strain/stress analysis; Vibration and noise analysis; Nondestructive testing and material evaluation; Microstructure and MEMS (MicroElectroMechanicalSystems) measurement; Design validation and optimization; Design of Instrumentation.

Qian Zou: Friction and wear modeling and testing; Tribology of engine cylinder kits; Friction phenomena in fasteners and joints; Elastohydrodynamic Lubrication (EHL); Thin film lubrication; Fluid dynamic bearings; Surface texturing.

10. Library Holdings

Since the proposed Master's program in Mechatronics is essentially a multi-disciplinary program based on the existing courses offered by SECS, very little new library collection development will be necessary. Appendix B shows a report of the library collection evaluation conducted by Kresge Library and a quick review of the section entitled "Currently Available Resources" confirms the above observation. Nevertheless, a few items identified under the section entitled "Resources Needed" are included in the budget (see Section 14).

11. Labs and Lab Equipment

The ECE department today can boast of a well known research center as well as a number of well equipped research and development laboratories, where state-of-the-art research in various areas of ECE are being pursued. These include:

- Applied Electromagnetics and Wireless Laboratory (AEWL)
- Automotive Mechatronics Laboratory (AML)
- Broadband Wireless Communication Laboratory (BWCL)
- Center for Robotics and Advanced Automation (CRAA)
- Chrysler Welding Laboratory (CWL)
- Chrysler Controls and Robotics Laboratory (CCRL)

- Embedded Engineering Research Laboratory (EERL)
- Intelligent Ground Vehicle Laboratory (IGVL)
- Microelectronics Systems Design Laboratory (MSDL)
- Micro-electromechanical System (MEMS) Laboratory

The ME department can also boast of a well known research center as well as a number of well equipped research and development laboratories, where state-of-the-art research in various areas of ME are being pursued. These include:

- Fastening and Joining Research Institute (FAJRI)
- Statics and Dynamics Laboratory
- Thermodynamics Laboratory
- Fluid Mechanics Laboratory
- Mechanics of Materials Laboratory
- Material Properties Laboratory
- Mechanical Systems CAD/CAM Laboratory
- Manufacturing Processes Laboratory
- Tribology Laboratory
- Two-phase Flow Research Laboratory
- Thermal Science Research Laboratory
- Optical Measurement and Quality Inspection Laboratory
- Laser Interferometry Application Laboratory
- Holographic Applications Laboratory
- Optical Non-destructive Testing Laboratory
- 3-D Computer Vision Laboratory
- Computational Fluid Dynamics and Heat Transfer Research Lab

12. Admission Requirements

The proposed program is designed to attract students and working professionals with a background in electrical engineering, computer engineering, mechanical engineering or systems engineering. Students who have undergraduate degree from other engineering disciplines and some experience working in a Mechatronic engineering field may also apply.

Candidates applying for admission to the program are required to have met the following criteria:

- Hold a Bachelor of Science degree in Mechanical Engineering, Electrical Engineering, Computer Engineering, Systems Engineering, or an equivalent degree from an ABET-accredited college or university.
- Hold a Bachelor of Science in Mathematics or Computer Science, or an equivalent degree from an accredited college or university, and some experience working in a Mechatronic engineering field.

In addition, all students must:

- Provide official transcripts of all completed college work.

- Have a minimum undergraduate overall GPA of 3.00.
- Submit a completed graduate application form.
- Submit two letters of recommendation, including one from a corporate supervisor and one from a professor in the students' undergraduate program, if you graduated within the last three years.

International students must also provide independent and accredited evaluation of their degree and courses for admission and comply with other foreign student admission requirements, as stated in the Graduate Catalog.

13. Degree Requirements

To fulfill the requirements for a Master of Science degree in Mechatronics, a student must complete at least 32 credits of graduate-level work, of which at least 16 credits must be from the Foundation Course group. The choice of the remaining 16 credits depends on whether a student elects a thesis option or not. For students electing a thesis option, 8 credits have to be taken for the thesis, and the remaining 8 credits must be selected from the Topical Course group. For students not electing a thesis option, at least 12 credits must be taken from the Topical Course group, whereas the remaining 4 Free Elective credits can be taken either as an additional topical course, a non-topical course, an independent study (ECE/ME 594), or a graduate engineering project (ECE/ME 690).

Foundation Courses (16 credits)

Complete 16 credits from multidisciplinary engineering courses. All students must take the key course ECE 575 and at least one ME course from the following list.

| | | |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|---|
| Required course - 4 credits | | |
| ECE 575 | Automotive Mechatronics | 4 |
| Select at least 4 credits from: | | |
| ME 521 | Dynamics | 4 |
| ME 530 | Kinematics and Mechanisms | 4 |
| | (Required for non ME students. Students with BS degree in ME cannot apply this course toward a Master's degree in Mechatronics) | |
| Select 8 credits from: | | |
| ECE 515 | Foundations of Electrical & Computer Engineering | 4 |
| | (Required for non EE/CE/ECE students. Students with BS degree in EE/CE/ECE cannot apply this course toward a Master's degree in Mechatronics) | |
| ECE 571 | Mixed Signal Embedded Systems | 4 |
| ECE 572 | Microcomputer-based Control Systems | 4 |
| ECE 575 | Automotive Mechatronics | 4 |

Topical Courses (at least 12 credits without thesis option, or at least 8 credits with thesis option)

Students not electing a thesis option are required to choose at least three disciplines from the four listed below, and take at least 4 credits from each. Students electing a thesis option are required to choose at least two disciplines from the four listed below, and take at least 4 credits from each.

Select 4 credits from electrical engineering discipline:

| | | |
|---------|--------------------------------------------|---|
| ECE 525 | Instruments and Measurements | 4 |
| ECE 583 | Fundamentals of MEMS | 4 |
| ECE 625 | Applications of Analog Integrated Circuits | 4 |
| ECE 632 | Wireless Communications | 4 |
| ECE 638 | Digital Image Processing | 4 |

Select 4 credit hours from computer engineering discipline:

| | | |
|---------|-----------------------------------------------|---|
| ECE570 | Microprocessor-based System Design | 4 |
| ECE 573 | Automotive Embedded Systems Design Validation | 4 |
| ECE 576 | Embedded Systems Design with FPGAs | 4 |
| ECE 671 | DSP in Embedded Systems | 4 |

Select 4 credit hours from the systems & control engineering disciplines:

| | | |
|---------|--------------------------------------------|---|
| ECE 520 | Signals and Systems | 4 |
| ISE 522 | Robotic Systems | 4 |
| ECE 523 | Robotics Systems and Control | 4 |
| ECE 678 | Introduction to Autonomous Vehicle Systems | 4 |
| SYS 630 | Optimal Control Theory | 4 |
| SYS 674 | Digital Control Systems | 4 |

Select 4 credit hours from mechanical engineering discipline:

| | | |
|--------|----------------------------------|---|
| ME 522 | Mechanical Vibrations | 4 |
| ME 523 | Acoustic and Noise Control | 4 |
| ME 555 | Combustion Processes | 4 |
| ME 557 | Internal Combustion Engines I | 4 |
| ME 582 | Fluid and Thermal Energy Systems | 4 |

Optional elective/independent-study/project (4 credits)

Students not electing a thesis option may choose either an elective course, or an independent study or a graduate engineering project from the following list. Prior approval of the ECE or ME Department Chair is required for an independent study or project.

| | | |
|----------------------------------------------------|------------------------------------------|---|
| Any graduate level CSE/ECE/ISE/ME/SYS course | Elective (topical or non-topical course) | 4 |
| ECE/ME 594 | Independent Study | 4 |
| ECE/ME 690 | Graduate Project | 4 |

Thesis course (8 credits)

Students electing a thesis option need to select a thesis supervisor and take 8 credits of either ECE 691 or ME 691. Successful completion and defense of a thesis is a prerequisite for earning thesis credits. All theses must conform to university standards (see “Master’s thesis/doctoral dissertation” in the Policies and Procedures section of SECS graduate catalog).

14. Recruitment Plan

We plan to advertise the new program by:

- Announcing it on the department and school websites,
- Announcing the new program in our senior design classes,
- Sending fliers to local industrial concerns and seeking help from the members of the SECS Advisory Board,
- Sending fliers to other colleges and universities in Michigan and Midwest, and
- Listing our program on the existing Mechatronics websites.

During the first four years, we have set very realistic and achievable goals of starting with 5 students and increasing the enrollment by 5 every year. We expect to achieve a steady-state enrollment of about 20 to 25 students in the program in the long run.

14. Needs and Costs of the Program

An estimate of the revenues and expenses associated with the proposed Master of Science program in Mechatronics is presented in Table 1 below. As this proposal is mostly based on existing course offerings, minimal additional resources are being requested. Specifically, these resources include two part-time faculty positions per year, and two additional teaching assistantships for alleviating the grading loads of regular faculty. The following assumptions were made in developing the Pro-forma shown in Table 1.

- Tuition Revenue: Based on a student survey and our current rate of recruitment, we assume that 5 new students will be recruited in the first year and at least 5 more per year thereafter. This will generate a steady-state revenue of more than \$100,000 per year from the third year. All students are assumed to carry full course loads, i.e., enroll for 16 credits per year.
- Expenses – Salary
 - a) Funds are being requested to support two new Teaching Assistants (TA) from the second year, because the number of TA positions currently available for ECE and ME departments (4 and 5, respectively) are barely adequate to sustain our existing programs.
 - b) Two part-time faculty positions (one for ME and one for ECE) are needed every year to offset the teaching loads of full-time faculty. The estimated cost is based on our current norm of hiring a new part-time instructor at an average salary of \$4,000 per year.

- **Operating Expenses**

About \$5,000 per year will be needed to purchase equipment, components, and supplies for Mechatronics laboratories.

Also, the cost of acquiring new library resources, as explained in the Library Collection Evaluation report and its Addendum (Appendix B), has been included. This includes the costs of the following three items:

- Books and Reference Sources,
- SAE Digital Library, and
- Funding to maintain the current resources.

Thus, from the tuition revenue alone, the proposed Master of Science program in Mechatronics is expected to be self-sufficient and generate additional net income for the university from the first year.

Table 1. Pro-forma Income Statement

Program Title: Master of Science in Mechatronics
 Program Start Date: Fall 2010

| | | Year 1 (FY2010) | Year 2 (FY 2011) | Year 3 (FY 2012) | Year 4 (FY 2013) | Year 5 (FY 2014) |
|---------------------------------------------|------|--------------------|---------------------|---------------------|---------------------|---------------------|
| Headcount of self-supported students | | 5 | 10 | 15 | 20 | 20 |
| Credit Hours Per Student | | 16 | 16 | 16 | 16 | 16 |
| Undergraduate | | 0 | 0 | 0 | 0 | 0 |
| Graduate | | 0 | 0 | 0 | 0 | 0 |
| Total Credit Hours | | 80 | 160 | 240 | 320 | 320 |
| Master's FYES | | 5 | 10 | 15 | 20 | 20 |
| Total FYES | | 5 | 10 | 15 | 20 | 20 |
| Tuition Rate Per Credit Hour | | | | | | |
| Undergraduate | | | | | | |
| Graduate ¹ | | \$511.00 | \$511.00 | \$511.00 | \$511.00 | \$511.00 |
| Other Fees | | | | | | |
| Revenue | | | | | | |
| Tuition | | \$40,880.00 | \$81,760.00 | \$122,640.00 | \$163,520.00 | \$163,520.00 |
| Other Fees | | | | | | |
| Total Revenue | | \$40,880.00 | \$81,760.00 | \$122,640.00 | \$163,520.00 | \$163,520.00 |
| Expenses | ACCT | | | | | |
| <i>Salaries/Wages</i> | | | | | | |
| Faculty Salaries | 6101 | | | | | |
| Visiting Faculty | 6101 | | | | | |
| Administrative | 6201 | | | | | |
| Clerical | 6211 | | | | | |
| Administrative – IC | 6221 | | | | | |
| Faculty Inload (Replacement Costs) | 6301 | | | | | |
| Faculty Overload | 6301 | | | | | |
| Part-time Faculty (2) | 6301 | \$8,000.00 | \$8,000.00 | \$8,000.00 | \$8,000.00 | \$8,000.00 |
| Graduate Assistants (2 from yr. 2) | 6311 | 0.00 | \$13,000.00 | \$13,000.00 | \$13,000.00 | \$13,000.00 |
| Wages | 6401 | | | | | |
| Out of Classification | 6401 | | | | | |
| Overtime | 6401 | | | | | |
| Student | 6501 | | | | | |
| <i>Total Salary Expenses</i> | | \$8,000.00 | \$21,000.00 | \$21,000.00 | \$21,000.00 | \$21,000.00 |
| Fringe Benefits | 6701 | \$816.00 | \$816.00 | \$816.00 | \$816.00 | \$816.00 |
| Total Salary and Fringe Benefits | | \$8,816.00 | \$21,816.00 | \$21,816.00 | \$21,816.00 | \$21,816.00 |
| Supplies and Services | 7101 | | | | | |
| Graduate Assistant Tuition ¹ | 7101 | \$0.00 | \$16,352.00 | \$16,352.00 | \$16,352.00 | \$16,352.00 |
| Facility Charges | 7101 | | | | | |
| Travel | 7201 | | | | | |
| Telephone | 7301 | | | | | |
| Equipment | 7501 | \$5,000.00 | \$5,000.00 | \$5,000.00 | \$5,000.00 | \$5,000.00 |
| Library ² | 7401 | \$20,200.00 | \$21,715.00 | \$23,342.00 | \$25,081.00 | \$26,932.00 |
| Total Operating Expenses | | \$25,200.00 | \$43,067.00 | \$44,694.00 | \$46,433.00 | \$48,284.00 |
| Total Expenses | | \$34,016.00 | \$64,883.00 | \$66,510.00 | \$68,249.00 | \$70,100.00 |
| Net Income(Loss) | | \$6,864.00 | \$16,877.00 | \$56,130.00 | \$95,271.00 | \$93,420.00 |

¹Based on Fall 2009 tuition rate

²Cost of Books & References, SAE Digital Library, and Funding to maintain current resources

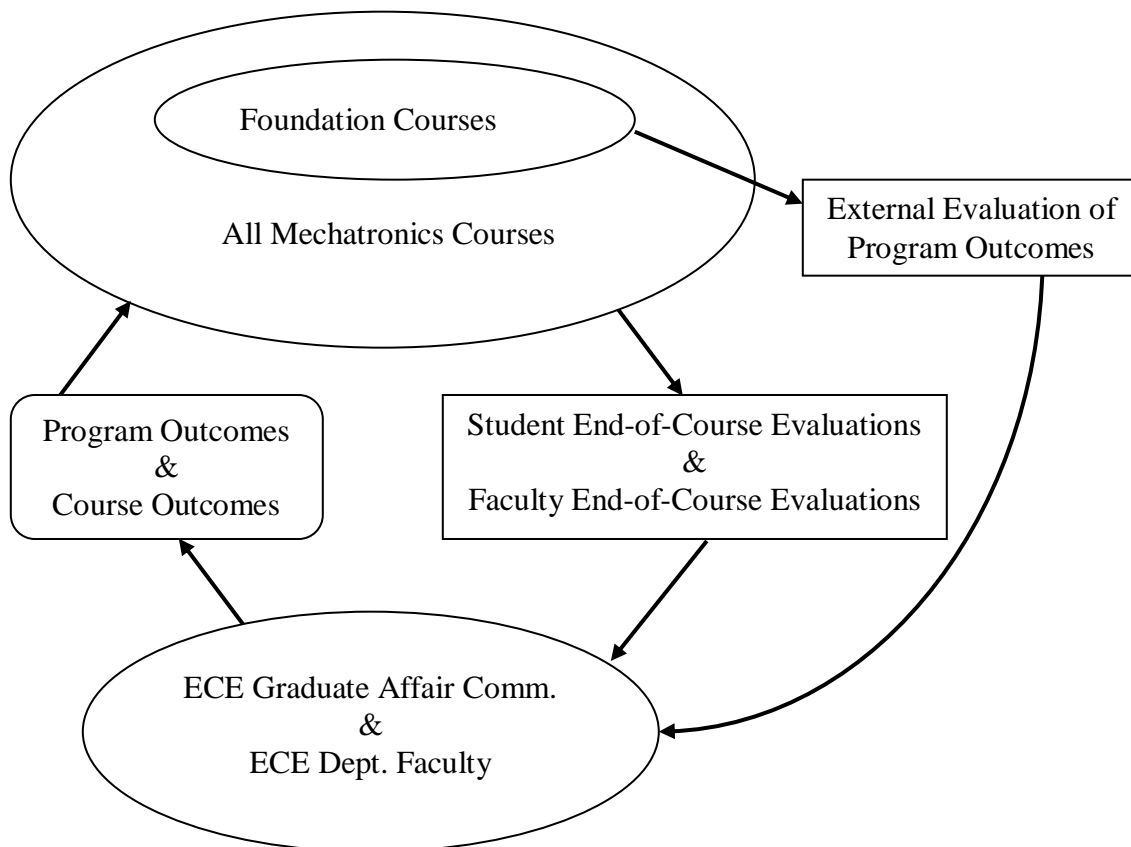
15. Plans for Assessment

Overview of ECE and ME Departments' Assessment Process.

The department of Electrical and Computer Engineering and the department of Mechanical Engineering are committed to continuously improve the quality of the Mechatronics program. The faculty have developed and implemented a formal plan to measure, assess, evaluate and improve the program in a systematic way.

The development of this plan began with setting the program outcomes that describe the skills necessary for successful modern engineering practice, and identifying outcomes for Mechatronics program that insure the skills necessary to achieve the general learning outcomes. The program assessment/improvement process involves both indirect and direct measures of the success of each course as well as overall measures of the educational program and of the assessment process itself. The overall success of a program is measured by whether the students of that program can demonstrate achievement of all outcomes when they graduate.

The Mechatronics program's assessment process is outlined in the following figure.



Measure

In order to assess the students' achievement, the ECE Dept. faculties have selected one direct measure and one indirect measure.

Direct Measure

The Mechatronics program has three foundation courses where students have the opportunity to demonstrate the achievement of the program outcomes. The foundation courses are designed to insure that all of the program outcomes are demonstrated. Student materials are collected from the foundation courses to provide evidence that the outcomes have been achieved. External evaluators, including faculty not directly involved with the course and departmental advisory board members, review these materials to establish whether the students in that class have achieved some or all of the program outcomes. Every semester, each department faculty reviews the results of these external evaluations and generates appropriate plans to improve the achievement of the program outcomes.

Indirect Measure

Each course in the Mechatronics program has a set of course outcomes, developed by the instructor and departmental Graduate Affairs Committees, which insure the logical sequence of topics necessary to the eventual achievement of the program outcomes. At the end of each semester, the students and faculty in each course rate how well that particular course section achieved its objectives. The faculty identifies the specific program outcome(s) achieved in the course and provide evidence in support of their contention. In addition, students and faculty are encouraged to comment on how well the course fits into the overall scheme of the program and to suggest improvements to the course, the course outcomes and the overall program of study. Both ECE and ME departments hold a faculty meeting at the beginning of each semester to review all external evaluations and end-of-course evaluations from the prior semester and develop any needed plan for improvement.

Documentation of Assessment Process.

All actions taken at each step of the assessment process will be documented in an online assessment database. The Chairs of ECE and ME departments, the chairs of the departmental Graduate Affairs Committees, the departmental Assessment Coordinators will update this database every time action is taken in the assessment process, and will solicit for improvements to the assessment process. In this way, a written record will be kept of both the assessment activities and of the process itself. This record will be used by the ECE and ME faculty to evaluate and improve the assessment process.

Faculty Involved in the Assessment Process

All ECE and ME faculty are involved in the assessment process.

16. Description of Proposed New Mechatronics Courses

No new courses are needed. The proposed program is based on existing courses.

APPENDIX – A

ECE, ME, and SYS COURSE DESCRIPTIONS

Both ECE and ME departments currently offer a wide range of courses for master's and doctoral students. These course offerings are continuously being updated by the departments' graduate affairs committees to keep track with the advancements in technologies. The catalog descriptions of the existing ECE, ME, and SYS graduate courses are provided below.

ELECTRICAL AND COMPUTER ENGINEERING

ECE 515

Foundations of Electrical and Computer Engineering (4 Credits)

A study of the foundations of electrical and computer engineering. The use of vectors, matrices, Fourier transforms, and probability in electrical and computer engineering. Computer-aided tools such as Matlab and C are used to solve problems in communications, digital logic, electronic circuit design, and applied electromagnetics.

ECE 520

Signal and Linear Systems Analysis (4 Credits)

Modeling and analysis of both continuous-time and discrete-time systems and signals. Time-domain and frequency-domain representation methods and transformations applied to electric circuits, mechanical systems and other dynamic systems. Fundamental theories of systems stability, controllability, observability and state-feedback control design. Computer simulation studies. Offered fall. Student must have permission of instructor.

ECE 523

Robotic Systems and Control (4 Credits)

Introduction to robotic systems and applications. Robotic forward and inverse kinematics. Task and path planning with motion controls. Jacobian matrix, differential motion and robotic statics. Redundant robots, mobile robots and multi-robot coordination. Robotic dynamics, position control and force control. Computer simulation and laboratory demonstration. Offered fall or winter.

ECE 525

Instrumentation and Measurements (4 Credits)

Errors in measurements, error corrections and minimization; transducers and their applications; signal conditioning and interfacing; electromagnetic compatibility and interference problems in instrumentation; measurement instrument and their characteristics. Measurement systems, signal analyzers and data acquisition systems; signal conversion; computer and microprocessor-based instrumentation. With project. (Previously EE 525.) Offered fall.

ECE 527

High-Frequency Electronics (4 Credits)

Transmission lines with sinusoidal and pulse excitation. Passive and active circuit components at high frequency. High frequency amplifiers, communication circuits, waveform generators and digital circuits. Introduction to high frequency measurements. (Previously EE 726, EE 626 and EE 527.) Student must have permission of instructor.

ECE 533

Random Signals and Processes (4 Credits)

Provides the foundation needed to work with the random signals which are encountered in engineering. Concept of a stochastic process. Characterization of random waveforms using power spectral density and the correlation function. Random signals in linear systems. Applications to engineering systems. Offered winter. Student must have permission of instructor.

ECE 534

Principles of Digital Communications (4 Credits)

Source coding, signal design, modulation and demodulation. The optimal receiver principle, synchronization, communications over narrow band channels, fading channels and error correction codes. Offered fall. Students must have completed a previous course in communications systems or have instructor permission.

ECE 537

Digital Signal Processing (4 Credits)

Analysis of discrete signals and systems. Introduction to digital filters including finite and infinite impulse response filter. Discrete and Fast Fourier Transformations. Application of digital signal processing. Offered Winter. Student must have a basic knowledge of linear systems and permission of instructor.

ECE 545

Electromagnetic Engineering (4 Credits)

Electromagnetic theory with applications. Diffraction, radiation, propagation, guided waves, optical transmission and resonant cavities. Offered winter. Student must have a background in vector calculus and basic electromagnetic theory. Prerequisite: At least one course from the core and theory group of courses.

ECE 546

Introduction to Electromagnetic Compatibility (4 Credits)

Review of EM basics related to ENMC applications. Analysis of EMI sources and receivers. Signal spectra, conducted and radiated emissions. Transmission line cross-talk. Introduction to shielding, filtering, and grounding. Electrostatic discharges (ESD). Circuit and system immunity. Signal spectra, conducted and radiated emissions. EMC requirements for component and system levels. US and European standards and their origin. Automotive EMC standards. EMC issues in vehicle multiplexing communication. With laboratory. Prerequisites: Undergraduate courses in electronic circuit design, electromagnetics, and communication systems

ECE 547

Antennas (4 Credits)

Introduction to antenna performance parameters including field patterns, power patterns, beam area, directivity, gain, beam efficiency, radiation intensity, antenna apertures, impedance, polarization, and the radio communication link. Dyadic Green's Function, Radiation from current elements such as a dipole and a current loop, far-zone fields, arrays of point sources. Antenna modeling and measurement techniques will be introduced. Course will incorporate labs and/or laboratory demonstrations.

ECE 550

Satellite-Based Positioning Systems (4 Credits)

Introduction to the fundamentals of satellite-based positioning systems with an emphasis on the Global Positioning System (GPS). Understanding of the GPS satellite constellation, coordinate systems, timing standards and GPS signal structure. Determination of position from the range measurements for different modes of positioning. Introduction to various ranging error sources and mitigation techniques. Impact of ranging errors and satellite geometry on 3-dimensional position error. Offered Fall or Winter. Student must meet prerequisites (ECE 325 or ECE 437).

ECE 557

Energy Conservation Systems (4 Credits)

Techniques for improving energy use in industrial and commercial applications. Topics include: energy accounting; energy auditing; energy conservation management; net energy analysis; second law methods of analysis; combined use energy systems; new technology for energy conservation; assessment of alternative technology. Credit cannot be received for both ECE 557 and ISE 557. Student must have permission of instructor.

ECE 567

Computer Networks (4 Credits)

Resource-sharing principles; communications and networks; packet switching; the ARPANET; network performance using principles of queueing theory; network design principles, capacity assignment; flow assignment; topological design. Other related topics. Student must have permission of instructor.

ECE 570

Microprocessor-based System Design (4 Credits)

Application of microprocessors and microcomputers to the solution of typical problems; interfacing microprocessors with external systems such as sensors, displays and keyboards; programming considerations, microcomputer system design. A laboratory design course, several short design projects and one large design project. This course integrates concepts learned in required courses and provides a design experience. The large design project includes cost/trade-off analysis, submitting a detailed written report and oral presentation of the project. Credit cannot be earned for more than one of CSE 470/570 and EE 470/570. Offered fall and winter. Student must meet prerequisite (CSE 502).

ECE 571

Mixed-Signal Embedded Systems (4 Credits)

This course will discuss the design and analysis of embedded mixed-signal systems. Topics include study and comparison of mixed-signal microcontroller architectures, programmable digital peripherals, programmable analog peripherals, sensor and actuator interfaces, optical and analog isolation, communication standards, and development tools. A final project will be approached in a top-down fashion involving, system specification, functional partition, trade-off analysis, component design, integration, and performance evaluation.

ECE 572

Microcomputer-based Control Systems (4 Credits)

Computer-aided engineering, analysis, design, evaluation of control systems. Model-based rapid-prototyping microcomputer/microprocessor-based hardware and software development of digital controllers, estimators, filters. Data acquisition, signal conditioning and processing circuits, graphics visualization. On-line system level and board-level microcomputer-based control experiments. Laboratory and projects emphasize real-time applications, programming and hardware integration. With laboratory. Offered winter.

ECE 573

Automotive Embedded Systems Design Validation(4 Credits)

Topics covered include, automotive electronics/embedded system requirements for controllers, transducers and sensor electronics, signal processing electronics, verification during design of automotive systems, speaker wire losses, Sneak circuit analysis, worst-case circuit analysis, design considering component tolerances, op-amp and resistor tolerance and non-ideal behavior analysis, thermal analysis, EMC analysis, FMEA (failure mode and effective) analysis, ground rules for high speed circuit, six sigma, failure analysis, fault tolerance, risk analysis, reliability issues, trade-offs in design, communication issues and delays in CAN, LIN and Flexray, simulation tools for validation, verification and testing, software in the loop and hardware in the loop tests, and software and hardware verification process.

ECE 575

Automotive Mechatronics (4 Credits)

Emphasis on electrical and electronics aspects of mechatronics. Topics include overview on analog & digital electronics circuits, noise isolation, impedance matching, MEMS devices, sensors & transducers, actuators & motors, power amplifiers and servo drivers, kinematics and dynamics and control of lumped parameter systems,. Introduction to CAE tools including Matlab modeling and simulation, LabView, PIC controllers, Simpler and/or Saber software. Simulation assignments, lab experiments and a term project.

ECE 581

Integrated Circuits and Devices (4 Credits)

Fundamentals of semiconductor electronics. Theory and operation of PN junctions and junction devices. MOS devices. Integrated circuits functional blocks, fabrication techniques, processing steps and equivalent circuits. Device modeling and simulation techniques. Offered Fall. Student must have permission of instructor.

ECE 583

Fundamentals of MEMS (4 Credits)

This course offers fundamentals of Micro-electro-mechanical Systems that involve multidisciplinary topics. In addition to systematic study of transduction principles and microfabrication technologies, variety of micro-scale transducers, including sensors and actuators, will be exemplified in detailed case study. This design-oriented course employs advanced MEMS and circuit simulation software for structural and circuit design of the MEMS devices. Students also have chance to fabricate their designed sensors and actuators through commercial or custom microfabrication.

ECE 585

VLSIC Circuits and Systems Design of Digital Chips (4 Credits)

Design techniques for rapid implementation and evaluation of Very Large Scale Integrated Circuits (VLSIC), including behavioral, functional, logic, circuit, device, physical IC fabrication, and layout issues. CMOS and pseudo NMOS technology, inverters, logic and transmission gates switching characteristics and processing. Reliability, yield and performance estimation. The course is project oriented. Students start with concepts and finish with actual Application Specific Integrated Circuits (ASICs) using modern CAD tool suites. Offered winter. ECE 585 replaces EE 585. This course also has a lab component.

ECE 587

Integrated Electronics (4 Credits)

Modern microelectronics processes and fabrication of integrated circuits. Crystal growth and wafer preparation, photolithography, dielectric and polysilicon film deposition, epitaxial growth, oxidation, diffusion, ion implantation, etching, metallization and integrated circuits layout principles. Introduction to MOS-based and bipolar junction transistor-based microcircuits design and fabrication. Fabrication processing simulation using SUPREM, with projects. Offered winter, even years.

ECE 594

Independent Study (2 OR 4 Credits)

Independent study in a special area of electrical and computer engineering. Topic must be approved prior to registration. Prerequisite: At least one course from the core and theory group of courses.

ECE 595

Special Topics (2 TO 4 Credits)

Study of special topics in electrical and computer engineering. May be taken more than once.

ECE 620

Multi-dimensional Signal Theory (4 Credits)

Random vector analysis. Generalized harmonic analysis. Correlation and spectrum analysis of stochastic fields. Multidimensional linear systems. Transformations of random fields in multidimensional systems. Elements of generalized functions and Hilbert spaces. Applications to signal field processing, image processing and antenna and sensor array design. Student must meet prerequisites (SYS 520

and at least one course from the core and theory group of courses).

ECE 625

Applications of Analog Integrated Circuits (4 Credits)

Building blocks of analog integrated circuits and their limitations; characteristics, analysis and applications of analog integrated circuits; principles of circuit and system design with analog integrated circuits. Offered winter. Student must meet the prerequisites (at least one course from the core and theory group of courses) and have permission of instructor.

ECE 632

Wireless Communications (4 Credits)

Introduction to wireless communication principles and systems. Wireless channel models, TDMA, FDMA, spread spectrum, CDMA, equalization, detection, estimation, coding, security, quality assessment of service and personal communications. The 2nd generation and 3rd generation wireless standards are also discussed. Offered fall, odd years. Student must meet prerequisites (EE 534 and at least one course from the core and theory group of courses) or have permission of instructor.

ECE 633

Signal Detection and Estimation Theory (4 Credits)

Noise analysis concept review, binary decision theory, multiple decision, sequential decision theory, nonparametric decision theory, fundamentals of estimation, sequential estimation theory, detection of coded information and error control. Student must meet prerequisites (EE 533 and at least one course from the core and theory group of courses).

ECE 634

Statistical Communication System Theory (4 Credits)

Harmonic analysis, sampling theory, stochastic process and correlation functions, linear systems response to random inputs, optimum linear systems (matched filters, Wiener filters) coherent and noncoherent filtering, nonlinear systems with random input (zero memory, square law, nth law devices), modulation theory, interference considerations. Student must meet prerequisites (EE 533 or SYS 517; at least one course from the core and theory group of courses).

ECE 635

Modulation and Coding (4 Credits)

Phase shift keying (PSK), quadrature amplitude modulation (QAM), continuous phase modulation (CPM), constant envelope modulation, power spectral density, bandwidth efficiency, block codes, convolutional codes and turbo codes. Offered winter, even years. Student must meet prerequisite (ECE 534).

ECE 638

Digital Image Processing (4 Credits)

Fundamentals of digital image processing; review of one-dimensional signal processing techniques; introduction to two-dimensional signals and systems; two-dimensional digital filtering; image enhancement techniques; statistical model based methods and algebraic techniques for image restoration; image data compression; image analysis and computer vision. Selected applications. Offered fall, odd years. Student must have knowledge of linear systems, and probability and statistics.

ECE 639

Advanced Digital Signal Processing (4 Credits)

An overview of random signals and systems; signal modeling techniques, signal enhancement techniques and their applications; adaptive filtering and its applications; introduction to wavelet transforms and its applications. Student must meet prerequisite (ECE 537).

ECE 645

Intelligent Control Systems (4 Credits)

Definition and paradigm for intelligent control; self-learning and supervised learning; hierarchical decision architecture; fuzzy logic, neural network, heuristics, genetic algorithm, optimum strategy and related topics; examples of intelligent and autonomous systems; computer simulation and visualization of applications. Student must meet prerequisite (at least one course from the core and theory group of courses) and have permission of instructor.

ECE 675

Automotive Mechatronics II (4 Credits)

Extensive review of software and modeling fundamentals, sensors, actuators, power train characteristics, automotive and industrial control systems; selected topics include engine and exhaust gas sensors; sensor interfaces; injection electronic circuits, engine and transmission controllers, pneumatic servos and active suspension; electromagnetic compatibility and issues related to system design, compatibility requirements, filtering, shielding/grounding, testing; emerging technologies in automotive mechatronics systems. Student projects. Credit cannot be received for both EE 675 and SYS 675. Student must meet prerequisites (EE 575 and at least one course from the core and theory group of courses).

ECE 678

Introduction to Autonomous Vehicle Systems (4 Credits)

Present applications and future roles of autonomous manned and unmanned vehicle systems. The course introduces theoretical and practical backgrounds for components and integration of autonomous vehicle systems. Topics include mobility dynamics and control, sensors & perception, cognition & decision, action & commands, computer, communications and integration. Case studies include lane following, obstacle avoidance, leader following, waypoint navigation and guidance. Homeworks, computer simulations and experiments. Prerequisite: Signals and systems background or permission of instructor

ECE 682

Field-Effect Devices (4 Credits)

Electronic structure of semiconductor surfaces. Concepts of surface states and surface charge. Metal-Semiconductor (MS) contacts: ohmic and rectifying. Conductivity modulation and the theory of JFET and MESFET transistors. Integrated device technology, including Silicon on Sapphire (SOS) and Silicon on Insulator (SOI) structures and their application. Student must meet prerequisites (EE 581 and at least one course from the core and theory group of courses).

ECE 683

Advanced VLSIC Analog/Digital Systems Design (4 Credits)

Full-custom design and analysis techniques of ASICs. Metal-Oxide-Semiconductor (MOS) devices, circuits and future trends. MOS processing and design rules. Extensive circuit simulation. Analog VLSIC basic functions. Graphical model representation. Amplifiers. Current mirrors. Computer Aided Design (CAD) of analog integrated circuits. Layout and design for testability considerations. Implementing integrated system design from circuit topology to patterning geometry to wafer fabrication. The course is project oriented. Students start with concepts and finish with testing and evaluating ASIC prototypes. Offered fall or winter. Student must meet prerequisite (at least one course from the core and theory group of courses) and have permission of instructor.

ECE 690

Graduate Engineering Project (2 TO 4 Credits)

Independent work on an advanced project in electrical engineering. Topic must be approved prior to registration.

ECE 691

Master's Thesis Research (2 TO 8 Credits)

Directed research leading to a master's thesis. Topic must be approved prior to registration. Prerequisite: At least one course from the core and theory group of courses.

ECE 725

Theory of Networks (4 Credits)

Network models of linear dynamic systems; network graphs and topological constraints, generalized equilibrium equations, time-frequency duality, energy and stability constraints, network passivity or activity, input-output representations, and state-transition matrices. Student must meet prerequisites (SYS 520 and at least one course from the core and theory group of courses).

ECE 741

Coherent Optics (4 Credits)

Current developments in coherent optics and holography; two-dimensional Fourier analysis, diffraction theory, Fourier transforming and imaging properties of lenses, holographic interferometry, optical data processing. With laboratory. Student must meet prerequisites (SYS 520 and at least one course from the core and theory group of courses).

ECE 794

Independent Study (2 TO 4 Credits)

Advanced independent study in a special area in electrical and computer engineering. Topic must be approved prior to registration.

ECE 795

Special Topics (2 TO 4 Credits)

Advanced independent study in a special area in electrical and computer engineering. Topic must be approved prior to registration.

MECHANICAL ENGINEERING

ME 521

Dynamics (4 Credits)

Generalized coordinates and matrix methods of analysis of the motion of particles and rigid bodies. Energy and momentum methods applied to mechanical systems. Euler and Lagrange methods applied to forces and motion. An introduction to mechanical vibrating systems. Keplerian motion and kinematics. Offered winter.

ME 522

Mechanical Vibrations (4 Credits)

Linear free and forced response of one and multiple degree of freedom systems. Equations of motion of discrete systems. Free vibration eigenvalues and eigenvectors. Applications to engineering systems including vibration isolation, rotating imbalance, vibration absorbers and balancing of rotating machinery. Project required. Offered fall.

ME 523

Acoustics and Noise Control (4 Credits)

Introduction to vibrations and waves; plane and spherical acoustic waves; sound generation, transmission and propagation; sound intensity and power; principles and definitions of noise control; sound and hearing; hearing conservation; community, building and industrial noise control; measurement of sound.

ME 525

Noise, Vibration and Harshness (4 Credits)

Basics of vibration and acoustics. Characteristics of sound waves. Sound generation and propagation. Human response to sound. Sound intensity. Vibration analysis and control. Modal analysis. NVH instrumentation and measurements. Noise control applications with emphasis to automotive applications. Project included.

ME 530

Kinematics and Mechanisms (4 Credits)

Basics of kinematics analysis, synthesis and mechanism design. Mechanisms' degrees of freedom and equivalent linkages. Analyze/Synthesize linkage positions, velocities and accelerations using graphical and analytical approaches. Cam/follower system introduction. Various types of gears and gear trains analysis. This course is cross listed with ME 430. Offered fall.

ME 538

Fluid Transport (4 Credits)

Continued study of the fundamentals of fluid mechanics and their applications; angular momentum principle, generalized study of various turbomachines, potential flow of inviscid fluids; laminar and turbulent boundary layer theory; dimensional analysis and similitude; compressible flow. With laboratory emphasizing engineering design. Offered fall.

ME 539

Computational Fluid Dynamics (4 Credits)

Overview of the physical and mathematical foundations of computational fluid dynamics (CFD). Practical numerical solution techniques for the Navier-Stokes equations; finite difference and finite volume methods, including discretization, stability analysis, time stepping and multigrid methods are covered. Discussion of grid generation and complex geometries. Introduction to commercial CFD software (Fluent/Gambit). Student must meet the corequisite or have approval of instructor and must have knowledge of a programming language.

ME 543

Polymeric Materials (4 Credits)

Fundamentals of plastic materials. Terminology and nomenclature for plastics. General topics dealing with plastics, such as structure, morphology, properties, etc. Focus on mechanical and physical properties and mechanical behavior of plastics. Plastics processing, testing, design and recycling is introduced. Project required.

ME 544

Plastics Processing Engineering (4 Credits)

Polymeric materials and their manufacturing related properties. Principles and design of extrusion, post extrusion processes, molding and forming processes. Rheological behavior of polymers, melt-flow characteristics, modeling and simulation. With project and laboratory.

ME 545

Plastics Product Design (4 Credits)

Design of plastic/composite products based on strength, stiffness, creep, impact, chemical and environmental attack. Effect of processing on part quality and performance. Design of plastic parts for joining and assembly. Use of CAD/CAM/CAE software for structural analysis and design optimization. Project required.

ME 548

Thermal Energy Transport (4 Credits)

Continued study of properties and descriptions of conduction, convection and thermal radiation heat transfer; thermal boundary layer theory; forced and natural convection, heat transfer correlations. Thermodynamics of thermal radiation, radiation intensity, surface properties and energy exchange.

Laboratory emphasizes experimental design and development of empirical relationships. Offered winter.

ME 549

Computational Heat Transfer (4 Credits)

Overview of the physical and mathematical foundations of computational heat transfer. Practical numerical solution techniques for the solution of steady and transient one- and multi-dimensional conduction, radiation, convection and phase change problems. Finite difference methods. Formulation of the discretization equations appropriate for the representation and solution of linear and nonlinear partial differential equations. Students are expected to complete several computer projects. This course is cross listed with ME 449. Student must meet prerequisite (ME 331).

ME 550

Computer-Aided Data Acquisition Analysis and Control (2 Credits)

Introduction to and "hands-on" experience with computer- aided data acquisition, analysis and control as it relates to fluid and thermal experimentation and measurements. Topics include computer hardware and software, a variety of measurement and control instrumentation, communication between instrumentation and computer. ASYST programming language, instrument operation and calibration, data acquisition and analysis. Design-oriented laboratory projects. Student must meet prerequisite (ME 582) or have permission of instructor.

ME 554

Solar and Alternate Energy Systems (4 Credits)

The analysis and design of energy conversion systems. Principles of optimum power transfer and efficiency. Availability analysis of systems for heating, chemical conversion and electrical generation. Emphasis on solar applications and alternative energy technology. Includes design project(s). With laboratory.

ME 555

Combustion Processes (4 Credits)

Thermodynamics of state, mixtures, Gibbs free energy; chemical equilibrium, stoichiometry; chemical reaction kinetics, reaction rate, mixing, catalyst action; fluid vaporization, condensation, atomization; applications, spark and compression ignition, continuous combustion. Student must meet prerequisite (ME 456) or equivalent.

ME 557

Internal Combustion Engines I (4 Credits)

An introduction to the thermodynamics, fluid mechanics and performance of internal combustion engines, including an introduction to engine types and their operation, engine design and operating parameters, ideal thermodynamics cycles, the thermodynamics of actual working fluids and the actual cycles, gas exchange processes, heat losses, performance, exhaust gas analysis and air pollution. With laboratory. Offered fall.

ME 559

Advanced Automotive Propulsion Systems (4 Credits)

An overview of prime movers suitable for vehicle propulsion. Topics include: a morphological description of various internal combustion engines, current and future passenger car engines and powertrains, energy alternatives, legislative issues, vehicle integration and suitable advanced technologies. The course typically will be taught by a team of industry experts. Student must meet prerequisite (ME 557) or have equivalent experience in I.C. engines.

ME 561

Analysis and Design of Mechanical Structures (4 Credits)

Use and methods of advanced mechanics of materials to design mechanical structures to meet elastic strength criteria. Topics include plates and shells, torsion of noncircular cross-sections, beams on elastic foundation, curved and composite beams, rotating disks, thick-walled cylinders, and energy methods. Offered fall.

ME 562

Fatigue Analysis and Design (4 Credits)

Emphasis is placed on analytical and predictive methods that are useful to design engineers in avoiding fatigue failure. The most current fatigue analysis methods, techniques and applications are introduced, which include the following: guidance for choosing and applying the analysis methods most appropriate to a fatigue situation; variable amplitude loading and statistical fatigue properties; engineering case studies involving the development of both fundamental and advanced analytical skills. Offered fall.

ME 563

Applied Elasticity (4 Credits)

Fundamentals of solid mechanics, stress-strain and equilibrium and compatibility equations, generalized Hook's law, boundary conditions. Plane strain and generalized plane stress, plane elasticity. Airy stress function, torsion and bending, St. Venant principle, introduction to thermoelasticity, and numerical methods. Offered winter.

ME 564

Mechanics of Composite Materials (4 Credits)

Introduction to composite materials. Forming procedures and manufacturing. Basic principles of fiber-reinforced composite materials. Introduction to micromechanics of a lamina. Macromechanical behavior of a laminate. Bending of laminated plates. Stress analysis of viscoelastic composite materials. Characterization and design of composite materials. Structural synthesis. Offered fall, even years.

ME 565

Experimental Stress Analysis (4 Credits)

Experimental determination of stress and strain in loaded members. Use of capacitance strain gage, resistance strain gages and rosettes and wheatstone bridges, optical strain gages and rosette, and two-dimensional photoelasticity and photoelastic coatings. Design of experiments and portable transducers which measure force, moment and displacement and deformations, etc. With laboratory. Offered winter.

ME 567

Optical Measurement and Quality Inspection (4 Credits)

Topics include the state-of-the-art optical methods such as holography, shearography, moire, three-dimensional computer vision, electronic speckle pattern interferometry and laser triangulation; with applications to measurement of displacement, vibrational mode shapes, material properties, residual stresses, three-dimensional shapes, quality inspection and nondestructive testing. Offered fall, winter.

ME 569

Finite Elements (4 Credits)

Structural analysis through matrix formulation using direct and variational methods; stiffness and flexibility matrices for triangular, quadrilateral and isoparametric elements in two and three dimensions. Finite element programs and available graphics hardware for data preparation. Offered fall.

ME 571

Theory of Plasticity (4 Credits)

Details of the fundamental mechanics of plastic deformation are explored. Yield criteria, hardening laws, constitutive relations, ductile fracture criteria and instability models are covered. An emphasis on theoretical concepts is made in order to prepare the student for metal forming problem solutions.

ME 572

Material Properties and Processes (4 Credits)

Study of mechanical behavior of real engineering materials and how they influence mechanical design. True stress/strain properties of materials, plastic deformation and fracture of materials, failure theories, fatigue damage under cyclic loading, creep and high temperature applications. Material properties of engineering metals, ceramics and composites. Behavior of materials during and after manufacturing processes such as stamping, drawing, extrusion, etc. Offered Student must meet prerequisite (ME 472).

ME 574

Manufacturing Processes (4 Credits)

Fundamentals and technology of machining, forming, casting and welding. Mechanics of cutting. Molding of polymers. Tolerancing and surface topography. Manufacturing considerations in design. Economics of manufacturing. Process assembly and product engineering. With laboratory. Offered fall, winter.

ME 575

Lubrication, Friction and Wear (4 Credits)

Study of fundamental wear mechanisms including: adhesive, abrasive, corrosive and surface fatigue. Boundary and hydrodynamic lubrication. Friction theories. Surface topography characterization. Applications: journal and ball bearings, gears and engine components. Offered spring, fall.

ME 576

Product and Process Development (4 Credits)

Topics include traditional and nontraditional approaches in product and process development and optimization, including conventional experimental mechanics and acoustic test methods. The Taguchi approach and other methods for design of experiments are used to study the interaction of variables and to attain optimization.

ME 577

Concurrent Engineering (4 Credits)

Principles of concurrent engineering including: manufacturing competitiveness, performance indicators, life-cycle management, strategic technology insertions, process re-engineering, cooperative work teams, supplier organization, information modeling and product realization taxonomy. Credit can only be received for one of the following: ME 577, ISE 577 or SYS 577. Offered winter.

ME 578

Mechanics of Metal Forming (4 Credits)

Study of mechanics, metallurgy and basic analytical and numerical methods needed to understand the analysis of metal forming processes. Topics include: introduction to plasticity, yield criteria, work hardening and plastic anisotropy; ideal work method, slab and upper-bound analyses; formability, springback and forming limit diagrams. Overview of using commercial finite element packages to simulate bulk and sheet metal forming. Offered fall.

ME 582

Fluid and Thermal Energy Systems (4 Credits)

Study of systems involving fluid and thermal phenomena. Includes conventional and unconventional energy conversion, fluid and thermal energy transport. Analysis, design and optimization of systems are emphasized using basic integral, differential and lumped parameter modeling techniques. The course bridges conventional engineering design disciplines with design-oriented laboratory projects. Offered fall.

ME 584

Automotive Engineering Design I (4 Credits)

Tire forces and moments, rolling resistance of tires, tractive effort and longitudinal slip, tires on wet surfaces, ride properties of tires; equation of motion and maximum tractive effort, aerodynamic forces and moments, power plant and transmission characteristics, prediction of vehicle performance, operating fuel economy, engine and transmission matching, braking performance. Offered fall.

ME 586

Reliability Methods in Engineering Design (4 Credits)

Theory and applications of probabilistic methods in the analysis and synthesis of engineering systems. Review of basic probability concepts, random variables and distributions and uncertainty quantification and propagation. First-order, second-order and advanced mean value reliability methods. Monte Carlo simulation, variance reduction techniques, sensitivity analysis and reliability-based design optimization. Implementation of probabilistic methods using Excel and Matlab. Offered winter.

ME 587

Mechanical Computer-Aided Engineering (4 Credits)

Introduction to the use of state-of-the-art finite element technology in mechanical engineering analysis. Fundamentals of computer graphics, solid modeling, finite element modeling and interactive design. Analysis and evaluation of linear static and dynamic mechanical systems. Includes design project(s) in various topics. Offered fall, summer.

ME 588

Mechanical Computer-Aided Manufacturing (4 Credits)

Use of CATIA in various aspects of manufacturing processes. GD&T and tolerance analysis; surface design, managing cloud points and reverse engineering; simulation of kinematics of machine tools; 3-axis surface machining; mold tooling design; CMM and measurement data analysis; assembly simulation and structural analysis, rapid-prototyping. Includes design projects in various topics. Offered winter. Student must have CATIA fundamentals or have permission of instructor.

ME 589

Fasteners and Bolted Joints (4 Credits)

A systems approach to the analysis, design and reliability of bolted joints under static and dynamic forces. System variables include the fastener, the joint, assembly tool, control methods, post assembly loads and relaxation and environmental factors. Laboratory experiments to illustrate torque tension relationship, role of friction, use of ultrasonics, effect of non-parallel contact and elastic interaction in bolted flanges. Project required. Offered winter. Student must meet prerequisite (ME 486).

ME 594

Independent Study (2 TO 4 Credits)

Independent Study in a special area in mechanical engineering. Topic must be approved prior to registration.

ME 595

Special Topics (2 TO 4 Credits)

Study of special topics in mechanical engineering. May be taken more than once.

ME 610

Continuum Mechanics (4 Credits)

Foundations in vector and tensor fields, kinematics of deformation, measures of strain and analysis of stress, equations of motion, compatibility conditions, constitutive equations, thermodynamics of deformation. Study of infinitesimal elasticity, ideal fluids, ideal elastoplasticity, processing, and material capabilities are studied in a systems context. (Previously ME 510). Offered winter, odd years.

ME 624

Vibration Analysis (4 Credits)

Linear vibrations in time and frequency domains. Lumped parameter mechanical systems. D'Alembert's and Hamilton's principles; Lagrange's equations. Free eigenvalue problem. Continuous systems. Response to non-periodic excitation. Numerical integration methods. Finite element and transfer matrix methods. Geared systems and torsional vibration of IC engines. Use of MATLAB and MSC/NASTRAN. Student must meet prerequisite (ME 522) or equivalent.

ME 638

Convective Transport Phenomena (4 Credits)

Development of the fundamental equations expressing conservation of mass and momentum principle. Navier-Stokes equations. Approximation techniques. Boundary layer theory. Introduction to turbulent transport processes. Hydrodynamics of two-phase flows. Offered winter, even years.

ME 639

Gas Dynamics (4 Credits)

Fundamental theories and applications of high-speed aerodynamics are the major subjects of the course. One-dimensional gas dynamics and wave motion. Shock waves in supersonic flow. Flow in ducts and wind tunnels. The equations of three-dimensional frictionless flow. Small-perturbation theory. Slender body theory. The similarity rules of high-speed flow and methods of measurement. Transonic flow. The method of characteristics. Student must meet prerequisite (ME 538).

ME 648

Thermal Transport Phenomena (4 Credits)

Development of the fundamental continuum equation expressing conservation of energy. Radiation and conduction heat transfer, extended surfaces, multi-dimensional conduction problems, and one-dimensional unsteady conduction problems. Convective heat transfer, thermal boundary layer theory, forced and natural convection, and two-phase flow phenomena. Offered fall.

ME 657

Internal Combustion Engines II (4 Credits)

Combustion characteristics, fuels, materials and design of internal combustion engines including: combustion in spark and compression ignition engines; engine heat transfer; fuels and fuel systems; engine balance and vibration; friction, lubrication and wear; valves and valve train; superchargers, turbochargers and auxiliary systems; variables affecting engine performance; engine design. With laboratory. (Previously ME 558). Offered winter. Student must meet prerequisite (ME 557).

ME 662

Advanced Fatigue Analysis and Design (4 Credits)

Fundamental fatigue models for multi-axial states of stress and strain, nonlinear fatigue damage theories, basics of elastic fracture mechanics, fatigue of welded joints, and theories of plasticity. Engineering case studies are considered. Offered winter, even years. Student must meet prerequisite (ME 562).

ME 665

Optical Methods in Experimental Mechanics (4 Credits)

Modern contemporary optical methods in experimental stress analysis, including digital speckle methods, correlation methods, x-rays and optical diffraction methods, digital holography, digital shearography and other digital optical methods. Emphasis on full field, non-contacting measurement and analysis of 3D-deformations, 3D-strains/stresses and vibration. With laboratory. Offered winter. Student must meet prerequisite (ME 567) or equivalent.

ME 669

Advanced Finite Elements (4 Credits)

Nonlinear finite element formulation for large deformation, plasticity and creep; incremental and iterative solution technique; design optimization; use of a finite element code in engineering applications such as stamping, metal forming, contact mechanics, buckling analysis, mechanics of composites and nonlinear transient dynamics. Offered winter, even years. Student must meet prerequisite (ME 569).

ME 674

Machining Processes (4 Credits)

Fundamentals of various machining processes including turning, milling, drilling and grinding. Fixturing and geometric errors produced by machine tools. Friction and wear of cutting tools. Influence of cutting fluids, tool design and tool material on cutting temperatures, work piece surface roughness and tool wear. Description of alternative machines and smart machine tools. Offered spring, odd years. Student must meet prerequisite (ME 574).

ME 675

Advanced Tribology (4 Credits)

In depth study of selected topics in tribology. Examples include: friction and wear theories, temperature rise due to frictional sliding, oil film thickness calculations, contact mechanics, friction and wear, mechanisms of metals, polymers and ceramics, engine and bearing tribology. Offered winter, odd years. Student must meet prerequisite (ME 575).

ME 678

Advanced Metal Forming (4 Credits)

The finite element simulation of metal forming processes using commercially available software. Focus on sheet metal stamping, tubular hydroforming and bulk metal forging. Mesh refinement, mass scaling, velocity scaling, element formulations, contact models, material models, CPU efficiency and postprocess solution interpretation are discussed. Project presentation typically required. Offered winter. Odd Years. Student must meet prerequisites (ME 578 and ME 569) or equivalent.

ME 684

Automotive Engineering Design II (4 Credits)

Continuation of Automotive Engineering Design I including: mechanics of handling, suspension, roll and ride; design of steering systems including: universal joints, vibration isolators, rack and pinion gears and tie rods. Design of doors, lift gates, hatchbacks and occupant environment. (Previously ME 585) Offered winter. Student must meet prerequisite (ME 584) or have permission of instructor.

ME 689

Advanced Fasteners and Bolted Joints (4 Credits)

Vibration loosening under vibration and impact loading, fatigue analysis, gasketed joints, fastener tribology, corrosion, Hydrogen Embrittlement, Stress Corrosion Cracking (SCC), elastic interaction, process optimization, nondestructive testing, ultrasonic control of fastener tightening, optical control of clamping load, failure analysis, case studies, graduate term paper. Offered Fall, even years. Student must meet prerequisite (ME 589).

ME 690

Graduate Engineering Project (2 TO 12 Credits)

Independent work on an advanced project in mechanical engineering. Topic must be approved prior to registration. May be taken more than once.

ME 691

Master's Thesis Research (2 TO 8 Credits)

ME 790

Doctoral Dissertation Research (2 TO 12 Credits)

Directed research toward the doctoral dissertation in mechanical engineering.

ME 794

Independent Study (2 TO 4 Credits)

Advanced independent study in a special area in mechanical engineering. Topic must be approved prior to registration.

ME 795

Special Topics (2 TO 4 Credits)

Advanced study of special topics in mechanical engineering. May be taken more than once.

SYSTEMS ENGINEERING

SYS 510

Systems Optimization and Design (4 Credits)

Classical optimization techniques including Lagrange multipliers and Kuhn-Tucker conditions. Computer techniques for system optimization including linear programming, constrained and unconstrained nonlinear programming. Introduction to global optimization, genetic algorithm, and dynamic programming. The course emphasizes a design experience involving system modeling, simulation and optimal design. Offered spring and summer. Student must have permission of instructor.

SYS 517

Probability and Its Engineering Applications (4 Credits)

Techniques and topics from probability of use to engineers, particularly those interested in manufacturing. Includes topics from statistics, control charts, propagation of error and tolerancing, analysis of queuing systems using birth and death processes and Markov chains, reliability, decision trees, etc. Offered winter, odd years.

SYS 520

Signal and Linear Systems Analysis (4 Credits)

Modeling and analysis of both continuous-time and discrete-time systems and signals. Time-domain and frequency-domain representation methods and transformations applied to electric circuits, mechanical systems and other dynamic systems. Fundamental theories of systems stability, controllability, observability and state-feedback control design. Computer simulation studies. Offered fall.

SYS 557

Energy Conservation Systems (4 Credits)

Techniques for improving energy use in industrial and commercial applications. Topics include: energy accounting; energy auditing; energy conservation management; net energy analysis; second law methods of analysis; combined use energy systems; new technology for energy conservation; assessment of alternative technology. Credit can not be received for both SYS 557 and ISE 557.

SYS 558

Electrical Energy Systems (4 Credits)

Generation, transmission and distribution of electrical energy. Analysis and design of three-phase circuits, per unit normalization, system design evaluation and load-flow, symmetrical components and stability. Offered winter.

SYS 563

Foundation of Computer-Aided Design (4 Credits)

Computer-aided design as the cornerstone of computer integrated manufacturing. Presentation and exploration of "generic" CAD architecture. Mathematical representations of CAD primitives, surfaces and solids and manipulation. Comparison of wire-frame, surface, 2-1/2 D and solid models. IGES, STEP, CALS and DXF standards. Description of "featurebased CAD" and the CAD manufacturing link. Offered fall.

SYS 569

Computer Simulation in Engineering (4 Credits)

Simulation as modeling tool for discrete-event and continuous systems; general principles of simulation; statistical models; input modeling; random variable generation; model building using a commercial simulation language; model verification and validation; determination of run length; output analysis; variance reduction techniques. Design and optimization of production service systems. Offered winter.

SYS 575

Automotive Mechatronics I (0 OR 4 Credits)

Overview of mechatronics; modeling, identification and simulation of electro-mechanical devices; introduction to computer-aided software; basic automotive sensors; basic actuators and power train devices; principles of automotive and industrial electronic circuits and control systems (analog and digital); principles of product design; mechatronics case studies. Credit cannot be received for both SYS 575 and EE 575.

SYS 577

Concurrent Engineering (4 Credits)

Principles of concurrent engineering including: manufacturing competitiveness, performance indicators, life-cycle management, strategic technology insertions, process re-engineering, cooperative work teams, supplier organization, information modeling and product realization taxonomy. Credit can only be received for one of the following: SYS 577, ISE 577 or ME 577.

SYS 583

Production Systems and Workflow Analysis (4 Credits)

Design issues to control the flow of material in manufacturing systems from forecast to finished product. Topics include characterization of production systems, aggregate planning and disaggregation to a master schedule, inventory control, MRP, JIT systems, scheduling and sequencing, project planning and resource balancing. Offered fall.

SYS 585

Statistical Quality Analysis (4 Credits)

Fundamentals of statistical quality control and their use in system design. Control charts for variables, control charts for attributes, cusum charts and other process quality monitoring topics. Sampling inspection plans. Fundamentals of design of experiments and their application to product/process design and improvement. Taguchi's approach to robust design and related topics. Credit can not be received for both SYS 585 and ISE 585. Offered winter. Students must have completed a course in probability.

SYS 587

Foundations of Systems Engineering (4 Credits)

Techniques for generation, analysis and verification of traceable product design requirements. System performance and structural modeling using object, behavioral and other models. Techniques for analysis of system for serviceability, reliability, maintainability and testability. System alternative trade-off study techniques. System life cycle and other tools for implementation of systems engineering techniques. Credit can not be received for both SYS 587 and ISE 587.

SYS 594

Independent Study (2 TO 4 Credits)

Independent study in a special area in systems engineering. Topic must be approved prior to registration.

SYS 595

Special Topics (2 TO 4 Credits)

Study of special topics in systems engineering. May be taken more than once.

SYS 623

Dynamics and Control of Robot Manipulators (4 Credits)

Cartesian and joint space representations and transformations. The Denavit-Hartenberg (D-H) convention and parameter tables. Robotic forward and inverse kinematics and task planning. Newton-Euler and Lagrangian dynamic models and formulations. Robotic joint servo control, position control, force control, compliant motion and many industrial application aspects. Computer numerical and graphical simulations. Offered winter. Student must meet prerequisite (SYS 520).

SYS 630

Optimal Control Theory (4 Credits)

Modern control theory applied to linear dynamical systems. Differential and difference equations; stability of optimal control systems; dynamic programming; calculus of variation and Pontryagin's minimum principle; optimally switched control systems, linear regulator problem; application of theory to practical control system design methodology; project involving the design of an optimal control system. Offered fall. Student must meet prerequisite (SYS 520).

SYS 631

Estimation and Control Theory (4 Credits)

Stochastic differential and difference equations; Luenberger observer theory; Kalman-Bucy filtering theory; design of stochastic optimal and microprocessor-based control systems; duality between optimal estimation and control problems; the separation principle; simulation and laboratory implementation of observers and filters in stochastic control system. Offered winter. Student must meet prerequisite (SYS 520).

SYS 632

Analysis of Nonlinear Control Systems (4 Credits)

Nonlinear systems modeling and analysis with various engineering applications. Special phenomena and nonlinear dynamics. Theory of nonlinear systems stability and stabilization. Controllability, observability, invertibility and linearizability of nonlinear control systems. Nonlinear feedback control, internal dynamics and nonlinear adaptive control. Advanced computer simulation studies. Offered fall. Student must meet prerequisite (SYS 520).

SYS 635

Adaptive Control Systems (4 Credits)

Classifications of self-tuning and adaptive systems; parameter estimation techniques, self-tuning regulators and state estimators, stability and convergence analysis; model reference adaptive systems using Lyapunov and hyperstability models; applications of adaptive control systems; computer simulation and laboratory experiments. Offered fall. Student must meet prerequisite (SYS 520).

SYS 645

Intelligent Control Systems (4 Credits)

Definition and paradigm for intelligent control; self-learning and supervised learning; hierarchical

decision architecture; fuzzy logic, neural network, heuristics, genetic algorithm, optimum strategy and related topics; examples of intelligent and autonomous systems; computer simulation and visualization of applications. Student must have permission of instructor.

SYS 674

Digital Control Systems (4 Credits)

Theoretical foundation needed to implement the microprocessor in control applications. Effects of sampling, data conversion, quantization, finite word length and time delays on system response and stability are examined. Pole-placement and observer/estimator techniques. Actual construction of a microcomputer-based controller culminates the course. Offered winter. Student must meet prerequisite (SYS 520).

SYS 675

Automotive Mechatronics II (4 Credits)

Extensive review of software and modeling fundamentals, sensors, actuators, power train characteristics, automotive and industrial control systems; selected topics include engine and exhaust gas sensors; sensor interfaces; injection electronic circuits, engine and transmission controllers, pneumatic servos and active suspension; electromagnetic compatibility and issues related to system design, compatibility requirements, filtering, shielding/grounding, testing; emerging technologies in automotive mechatronics systems. Student projects. Credit cannot be received for both SYS 675 and EE 675. Student must meet prerequisite (SYS 575).

SYS 680

Engineering Decision in Analysis (4 Credits)

Consideration of risk and uncertainty in decision criteria for resource allocation. Mathematical programming in engineering applications for multi-attribute utility analysis. Offered fall.

SYS 690

Graduate Engineering Project (2 TO 4 Credits)

Independent work on an advanced project in systems engineering. Topic must be approved prior to registration.

SYS 691

Master's Thesis Research (2 TO 8 Credits)

Directed research leading to a master's thesis. Topic must be approved prior to registration.

SYS 721

Large-Scale Dynamic Systems (4 Credits)

Analysis using a systems methodology including state variable modeling and multilevel structure. Structural stability, dynamic reliability, aggregation and decomposition. Application to estimation and control of large systems. Student must meet prerequisite (SYS 520).

SYS 722

Linear Multivariable Systems (4 Credits)

Fundamental and state-of-the-art modeling, analysis and design of linear multivariable dynamic systems. The role of polynomial matrices and differential operators in the description and structural realization of multivariable systems. Concepts of multivariable poles, zeros, Nyquist arrays and generalized root loci. Algebraic design methods based on state feedback observers, and model-matching. Inverse Nyquist and characteristic locus techniques as extensions of classical control design. Student must meet prerequisite (SYS 520).

SYS 731

Stochastic Optimal Control and Estimation Theory (4 Credits)

Foundation of stochastic optimal control and estimation theory. Continuous-time and discrete-time stochastic linear and nonlinear systems; analysis and design of stochastic optimal control systems; nonlinear filtering smoothing and prediction theory; and adaptive control estimation. Offered fall, odd years. Student must meet prerequisite (SYS 630).

SYS 794

Independent Study (2 TO 4 Credits)

Advanced independent study in a special area in systems engineering. Topic must be approved prior to registration.

SYS 795

Special Topics (2 TO 4 Credits)

Advanced study of special topics in systems engineering. May be taken more than once.

APPENDIX – B

Library Collection Evaluation



MEMORANDUM

To: Manohar Das, Chair, Department of Electrical and Computer Engineering, SECS
Gary Barber, Chair, Department of Mechanical Engineering, SECS

From: Shawn V. Lombardo, Collection Development Coordinator, Kresge Library
Millie Merz, Associate Professor, Kresge Library

Date: November 17, 2009

Re: Library collection evaluation to support proposed MS in Mechatronics

In developing this collection evaluation, we reviewed the draft proposal for a Master of Science program in mechatronics. Below is a brief description of the resources currently available, those that should be acquired, and a five-year cost estimate for these additional library resources.

Currently Available Resources

Journals, Conference Proceedings and Monographs/Book Series

The program proposal notes that mechatronics represents a “hybrid field of mechanical engineering, electrical engineering and control engineering.” Currently, the library subscribes to a number of important publisher journal packages that would support this interdisciplinary program. These include the complete *IEEE (Institute of Electrical and Electronics Engineers) Digital Library*, which consists of IEEE journals, transactions and magazines from 1988 to present, as well as IEEE conference proceedings and standards, and IET (Institute of Engineering and Technology) periodicals and conference proceedings. The library also maintains online access to all Association of Computing Machinery (ACM) journals, magazines, transactions and conference proceedings through the *ACM Digital Library* and all 24 journals of the ASME (American Society of Mechanical Engineers), with coverage from 2000 to present.

With special funding from Provost Moudgil, the library subscribes to the *Science Direct Freedom Collection*, Elsevier’s collection of approximately 1500 eJournals, including more than 140 computer science titles and 210 electrical, mechanical and control engineering titles. Specifically, the *Freedom Collection* provides access to relevant titles such as *Mechatronics; Robotics and Autonomous Systems; Control Engineering Practice*; and *CIRP Annals* and titles from the SME (Society of Manufacturing Engineers). Other important journals are available through the Springer and Sage packages, including

Journal of Micro-Nano Mechatronics, Autonomous Robots, Journal of Intelligent & Robotic Systems, Experimental Mechanics, and the International Journal of Robotics Research. These journal packages are multi-disciplinary, and include numerous other titles that would be relevant to students and faculty engaged in mechatronics research. In fact, through its various journal packages, the library maintains subscriptions to most of the periodicals listed in the *Mechatronics Information Guide* on the website of the Institution of Mechanical Engineers (<http://www.imeche.org>).

Last year, the library also purchased a Springer eBook package for almost all Springer monographs and book series published between 2005 and 2009. This important collection includes hundreds of relevant monographs such as *Modelling in Mechanical Engineering and Mechatronics, Recent Advances in Mechatronics, and Design of Embedded Control Systems.* This collection also includes the critically important (and expensive) book series *Lecture Notes in Computer Science* and *Lecture Notes in Electrical Engineering*, among other monographic series.

Indexes

To access the journal and conference literature in electrical and mechanical engineering and computer science, Kresge Library maintains subscriptions to a number of online indexes. The most important of these are *Compendex* (via *Engineering Village*), a bibliographic index to journals and conference proceedings in engineering and computing from 1969 to the present, and *Science Citation Index* (available online through the *Web of Science* platform), which indexes journals from 1980 to present in the sciences. It is important to note that *Engineering Village*, the most important mechanical engineering index, is funded each year by the School of Engineering and Computer Science (SECS); this funding must continue in order to maintain the library's subscription. The library also provides access to *Biotechnology and Bioengineering Abstracts, Applied Science and Technology Abstracts*, which covers both academic and trade journal literature in science and technology, and *Computer Database*, which covers news and products for computers, electronics, etc.

Resources Needed

The program proposal indicates in Section 10 (Library Holdings) that no additional funding is needed to strengthen the library's current holdings because the program will be based primarily on existing graduate course offerings, with only five new courses. However, our evaluation of the library's collection reveals a few areas that should be strengthened in order to support teaching and research in mechatronics adequately.

First, the library should expand its collection of monographs on mechatronics and related topics by acquiring the 2008 edition of *Mechatronics Handbook* to update the library's 2002 edition; (\$176) and the *Mechatronics Sourcebook*, among other titles. The average cost of a book in this field is approximately \$150; we anticipate that purchasing six to seven titles will be sufficient to support the program. Funding for these monographs is included in Table 1.

Given that the SECS will teach ECE 573 (Automotive Embedded Systems Design Validation) and ECE 678 (Introduction to Autonomous Vehicle Systems) regularly as part of the mechatronics program, and the importance of mechatronics to automotive manufacturing, the library recommends beginning a subscription to the *International Journal of Vehicle Design* (\$1687). Additionally, the library has no access to ASME conference proceedings. While the entire ASME Digital Library of conference proceedings would cost \$7,000, it seems sufficient for the library to obtain one of the proceedings subsets. Funding for these serials also is included in Table 1.

Finally, Table 1 includes funding to cover anticipated annual inflationary cost increases for the library's current journals, eBook collections and research databases (historically averaging eight to ten percent or more per year) that support mechanical, electrical and control engineering, and computer science.

Without additional funding, the library cannot guarantee that we will be able to maintain subscriptions even to our current resources. Therefore, we ask that the library be given funds each year to assist us in continuing to subscribe to the necessary resources for faculty and students in the mechatronics program.

C: Julie Voelck, Dean of the Library
 Louay Chamra, Dean of the School of Engineering and Computer Science
 Jan Tigar-Kramer, Library Liaison to the School of Engineering and Computer Science
 Anne Switzer, Library Representative to the University Senate

**Table 1: Estimated Library Acquisitions Costs
 for the Proposed MS in Mechatronics**

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|-------------------------------------------------------------|-----------------|-----------------|-----------------|------------------|------------------|
| Books & reference sources ¹ | \$ 1,000 | \$ 1,050 | \$ 1,103 | \$ 1,158 | \$ 1,216 |
| <i>International Journal of Vehicle Design</i> ² | \$ 1,687 | \$ 1,856 | \$ 2,041 | \$ 2,245 | \$ 2,470 |
| ASME Proceedings (subset) ² | \$ 2,500 | \$ 2,750 | \$ 3,025 | \$ 3,328 | \$ 3,660 |
| Funding to maintain current resources ² | \$ 3,000 | \$ 3,165 | \$ 3,339 | \$ 3,523 | \$ 3,716 |
| Total | \$ 8,187 | \$ 8,821 | \$ 9,508 | \$ 10,253 | \$ 11,062 |

¹Years 2-5 include a 5% inflationary increase.

²Years 2-5 include a 10% inflationary increase.



Kresge Library
Rochester, Michigan 48309-4401

MEMORANDUM

To: Manohar Das, Chair, Department of Electrical and Computer Engineering, SECS
Gary Barber, Chair, Department of Mechanical Engineering, SECS

From: Shawn V. Lombardo, Collection Development Coordinator, Kresge Library
Millie Merz, Associate Professor, Kresge Library

Date: December 14, 2009

Re: Addendum: Library collection evaluation to support proposed MS in Mechatronics

Originally, we did not include the Society of Automotive Engineers (SAE) Digital Library in the collection evaluation for the MS in Mechatronics because we assumed that the cost would be prohibitive. After consultation with faculty in the School of Engineering and Computer Science, we concur that the most important library acquisition for the proposed program would be an annual subscription to the SAE Digital Library. The current subscription price of \$15,000 per year quoted by SAE includes site-wide access to SAE technical papers from 1998 to present. This price is valid until June 2010; thereafter, the price will increase. Assuming that the new program will not begin until Fall 2010, and therefore a subscription would not begin until then, a five-year cost estimate, with an eight percent annual inflationary increase built in beginning in Year 1, is included below; actual costs for the database may differ significantly from this estimate.

| | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
|--------------------------------------------------------|----------|----------|----------|----------|----------|
| SAE Digital Library (1998-present) Annual Subscription | \$16,200 | \$17,500 | \$18,900 | \$20,400 | \$22,000 |

C: Julie Voelck, Dean of the Library
Louay Chamra, Dean of the School of Engineering and Computer Science
Jan Tigar-Kramer, Library Liaison to the School of Engineering and Computer Science
Anne Switzer, Library Representative to the University Senate