UNIVERSITY OF MICHIGAN
College of Engineering
Curriculum Committee Meeting
Tuesday, November 23, 2021

Attending: Fred Terry (Chair), Robert Bordley, Yavuz Bozer, Jessy Grizzle, Saadet Guralp, George Halow, Chad Jenkins, Amir Kamil, Leena Lalwani, Ryan Latimer, Xiaogan Liang, Paige Lighthammer, Cameron Loutitt, Radoslaw Michalowski, Ken Powell, Eric Rutherford, Katie Snyder, Kalyn Veal, Kerri Wakefield, Steven Yalisove, Won Sik Yang

Support Staff: Kerry Beers, Betsy Dodge, Matthew Faunce, Stacie Vaughn

Call to Order: 1:33pm

Adjourned: 3:05pm

AGENDA

1. Approval of 10.26.2021 Meeting Minutes (Page 3)
2. Master of Engineering (M.Eng.) in Aerospace Leadership Program Proposal (Page 5)
    a. AEROSP 501, 502, and 505 CARFs were conditionally approved
    b. AEROSP M.Eng. awaits the signing of Insead MOU prior to upcoming 12.8.2021 Faculty Meeting.
3. Online Transfer Credit Policy Proposal (Page 34)
    a. Proposal calls to eliminate the 12-credit maximum for transfer credit in the online format – vote tabled to 12.7.2021
    b. Suggestion given to raise cap on credits instead of removing 12 credit cap, general concerns surrounding proposal also raised.
    c. Kerri Wakefield will reach out to UPAGE group advisors for their opinion and return to CoE CC meeting on 12.7.2021 to share findings and ask for a vote on policy.
4. Robotics Undergraduate Program Proposal (Page 44)
    a. Based on feedback from Alec Galimore, some courses may be retitled and any necessary CARFs will be presented to the CoE CC at a future date.

CARF SUMMARIES

PAGE	SUBJECT	COURSE #	ACTION	SUMMARY	EFFECTIVE TERM	MIN. GRADE REQ. FOR ENF. PREPREQ	APPROVED	NOTES & REVISIONS	TABLED
87	AEROSP	501	NEW		FT 2022	NO	CONDITIONAL APPROVAL	Signature to be obtained from Home Dept. Edit course description to remove, "this course"	
92	AEROSP	502	NEW		FT 2022	NO	CONDITIONAL APPROVAL	Signature to be obtained from Home Dept. Add Rackham student credit to Course Credit Type	

96	**AEROSP**	**505**	**NEW**		**FT 2022**	**NO**	**CONDITIONAL APPROVAL**	Signature to be obtained from CoE CC Rep and Home Dept.	
100	**BIOMEDE**	**350**	**MOD**	Changing prerequisites to make the registration process easier for students. Overrides will no longer be required. Change to course description.	**FT 2022**	**C-**	**X**		
103	**CEE**	**518**	**NEW**		**FT 2022**	**NO**	**X**		
113	**EECS**	**449**	**NEW**		**FT 2022**	**C**	**X**		
141	**EECS**	**471**	**NEW**		**FT 2022**	**C**	**X**		
157	**EECS**	**601**	**NEW**		**FT 2022**	**NO**	**CONDITIONAL APPROVAL**	Change course title to "Reinforcement Learning Theory"	
165	**IOE**	**635**	**DEL**	Deletion CARF so that a New Course can be added under the same number.	**FT 2022**	**NO**	**X**		
168	**IOE**	**635**	**NEW**		**FT 2022**	**NO**	**X**		
189	**NERS**	**544**	**MOD**	Changing course description and changing credit hours from 2 to 3 credits.	**WT 2023**		**CONDITIONAL APPROVAL**	Edit course description down to 50 words and edit first sentence to "Monte Carlo methods are applicable…"	

UNIVERSITY OF MICHIGAN
College of Engineering
Curriculum Committee Meeting
Tuesday, November 23, 2021

Attending:

Call to Order:

Adjourned:

AGENDA

1. Approval of 10.26.2021 Meeting Minutes (Page 3)
2. Master of Engineering (M.Eng.) in Aerospace Leadership Program Proposal (Page 5)
3. Online Transfer Credit Policy Proposal (Page 34)
4. Robotics Undergraduate Program Proposal (Page 44)

CARF SUMMARIES

PAGE	SUBJECT	COURSE #	ACTION	SUMMARY	EFFECTIVE TERM	MIN. GRADE REQ. FOR ENF. PREPREQ	APPROVED	NOTES & REVISIONS	TABLED
87	AEROSP	501	NEW		FT 2022	NO		Signature to be obtained from Home Dept.	
92	AEROSP	502	NEW		FT 2022	NO		Signature to be obtained from Home Dept.	
96	AEROSP	505	NEW		FT 2022	NO		Signature to be obtained from CoE CC Rep and Home Dept.	
100	BIOMEDE	350	MOD	Changing prerequisites to make the registration process easier for students. Overrides will no longer be required. Change to course description.	FT 2022	C-			
103	CEE	518	NEW		FT 2022	NO			
113	EECS	449	NEW		FT 2022	C			
141	EECS	471	NEW		FT 2022	C			

157	**EECS**	**601**	**NEW**		**FT 2022**	**NO**			
165	**IOE**	**635**	**DEL**	Deletion CARF so that a New Course can be added under the same number.	**FT 2022**	**NO**			
168	**IOE**	**635**	**NEW**		**FT 2022**	**NO**			
189	**NERS**	**544**	**MOD**	Changing course description and changing credit hours from 2 to 3 credits.	**WT 2023**				

UNIVERSITY OF MICHIGAN
College of Engineering
Curriculum Committee Meeting
Tuesday, October 26, 2021

Attending: Fred Terry (Chair), Jeremy Bassis, Robert Bordley, Yavuz Bozer, Saadet Guralp, Amir Kamil, Leena Lalwani, Ryan Latimer, Xiaogan Liang, Cameron Loutitt, Frank Marsik, Radoslaw Michalowski, Yulin Pan, Roxanne Pinsky, Kevin Pipe, Ken Powell, Katie Snyder, Steven Yalisove, Won Sik Yang
Support Staff: Kerry Beers, Betsy Dodge, Matthew Faunce, Stacie Vaughn

Call to Order: 1:33pm

Adjourned: 2:15pm

AGENDA

1. Approval of 10.12.21 Meeting Minutes (Page 3) Approved 1:33pm

CARF SUMMARIES

PAGE	SUBJECT	COURSE #	ACTION	SUMMARY	EFFECTIVE TERM	MIN. GRADE REQ. FOR ENF. PREPREQ	APPROVED	NOTES & REVISIONS	TABLED
6	AEROSP	495	MOD	Change to Repeatability to allow credit for repeat credit	WT 2022	NO	X		
9	CHE	517	MOD	Removing cross-listing of PHARMSCI 717.	WT 2022	NO	X	Removing cross-listing of PHARMSCI 717.	
12	EECS	388	MOD	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	WT 2022	NO	CONDITIONAL APPROVAL	Specific verbiage for Enforced Prerequisite to come from URO.	
15	EECS	482	MOD	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	WT 2022	C	CONDITIONAL APPROVAL	Specific verbiage for Enforced Prerequisite to come from URO.	
18	EECS	483	MOD	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	WT 2022	C	CONDITIONAL APPROVAL	Specific verbiage for Enforced Prerequisite to come from URO.	
21	EECS	484	MOD	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	WT 2022	C	CONDITIONAL APPROVAL	Specific verbiage for Enforced Prerequisite to come from URO.	
24	EECS	485	MOD	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	WT 2022	C	CONDITIONAL APPROVAL	Specific verbiage for Enforced Prerequisite to come from URO.	

27	**EECS**	**490**	**MOD**	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	**WT 2022**	**C**	**CONDITIONAL APPROVAL**	Specific verbiage for Enforced Prerequisite to come from URO.	
30	**EECS**	**492**	**MOD**	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	**WT 2022**	**C**	**CONDITIONAL APPROVAL**	Specific verbiage for Enforced Prerequisite to come from URO.	
33	**EECS**	**493**	**MOD**	Add statement to Enforced Prerequisite "Enrollment in one minor elective allowed for Computer Science Minors."	**WT 2022**	**C**	**CONDITIONAL APPROVAL**	Specific verbiage for Enforced Prerequisite to come from URO.	
36	**CLIMATE**	**485**	**NEW**		**FT 2022**	**C**	**X**	Cross-Listed with CLaSP-SPACE 485.	
47	**CLIMATE**	**747**	**MOD**	Change to title and course description	**FT 2022**	**NO**	**CONDITIONAL APPROVAL**	Cross-Listed with CLaSP-SPACE 747. Remove the allowable repeat for credit. Update course description surrounding proposals, reword mention of "NSF GSRF and NASA FINESST programs" to general terms.	
50	**SPACE**	**571**	**NEW**		**FT 2022**	**NO**	**CONDITIONAL APPROVAL**	Condense course description to 50 words or less and remove "Aim of course" from the first sentence.	
62	**EECS**	**201**	**MOD**	Adding ROB 102 as an option for Enforced Prerequisite	**FT 2022**	**C**	**X**		
65	**EECS**	**280**	**MOD**	Adding ROB 102 as an option for Enforced Prerequisite	**FT 2022**	**C**	**X**		
68	**EECS**	**572**	**NEW**		**FT 2022**	**NO**	**CONDITIONAL APPROVAL**	Add further description to Advisory Prerequisite section regarding the mathematical rigor needed for students. Edit "and more" in course description to "and related topics."	
91	**CLIMATE**	**748**	**NEW**		**WT 2023**	**NO**	**CONDITIONAL APPROVAL**	Cross-Listed with CLaSP-SPACE 748. Remove the allowable repeat for credit.	

COLLEGE OF ENGINEERING
AEROSPACE ENGINEERING
UNIVERSITY OF MICHIGAN

Master of Engineering (M.Eng.) in Aerospace Leadership

Online Master's Degree Program

Proposal: create an online Master of Engineering in Aerospace Leadership degree, delivering accelerated and balanced teachings in Aerospace Science and Engineering, Business Application, and Aerospace Enterprise Integration (blend between systems engineering, a Capstone project, and essential leadership and business skills).

The proposed program is endorsed by the Aerospace Engineering Department Chair, the College of Engineering (CoE) Associate Dean for Graduate & Professional Education, the Aerospace Engineering Industrial Advisory Board (IAB), the Center for Entrepreneurship (CFE), and INSEAD leadership – reference Appendix II for endorsement letters.

The proposed framework can be applied to other College of Engineering Departments, with minimal creation of incremental assets, upon successful launch in Aerospace.

Core Faculty

Program Director	George F. Halow, Professor of Practice, Aerospace Engineering
Program Faculty	Aerospace Engineering: Kenneth Powell, Krzysztof Fidkowksi, Karthik Duraisamy, Venkat Raman, Mirko Gamba, Benjamin Jorns, Veera Sundararaghavan, Anthony Waas, Dennis Bernstein, Dimitra Panagou, Ilya Kolmanovsky, George Halow, Joaquim R. R. A. Martins, James Cutler CLaSP: Nilton Renno ISD: Bob Bordley CFE: TBD INSEAD: Multiple
Internal Advisory Committee *(Proposed)*	Carlos Cesnik, Professor, Aerospace Engineering Karthik Duraisamy, Professor, Aerospace Engineering Lola Eniola-Adefeso, Associate Dean for Graduate & Professional Education, College of Engineering Jonathan Fay, Executive Director, Center for Entrepreneurship Mingyan Liu, Chair, Electrical and Computer Engineering Debbie Mero, Senior Executive Director, RPM Ken Powell, Professor, Aerospace Engineering Tony Waas, Chair, Aerospace Engineering (and committee chair)

External Advisory Board

- Karen Albrecht, retired executive Lockheed Martin
- Mauro Atalla, Sr. Vice President, Engineering & Technology, Collins Aerospace
- Corey Brooker, Senior Manager, Lockheed Martin
- Kathryn Elliott, Capability Manager, Performance and Aerothermal, Rolls-Royce
- Marc Fischer, Sr. Vice President - Engineering, Cabin & Cargo, Airbus
- Trudy Kortes, Director, Technology Demonstration Missions Program, NASA
- Ben Marchionna, Director of technology & Innovation, Electra.Aero
- Kevin Michaels, Founder/Managing Director, Aerodynamic Advisory (and chair)
- Juan Carlos Ortiz, Sr. VP Programs Business Development, Aernnova
- Raenaurd Turpin, Director of Architecture, Boeing

A. Summary

The Master of Engineering in Aerospace Leadership is an intensive, 27-credit online master's degree program which combines the educational power of two of the world's top institutions in their disciplines – Michigan Engineering and INSEAD.

The educational goals are to provide:

1) an advanced technical education in a specific area of expertise – perhaps an area of expertise of a company division into which the graduate will transfer upon completion of the degree – at a level sufficient for decision-making, as opposed to basic research and invention
2) a core set of essential business skills in order to manage technical delivery, but not as comprehensive as that provided in an MBA program
3) a rigorous, hands-on integration and application of the educational materials in a real and tangible industrial environment

Target candidates are high-performing engineers with 3-7 years of experience, career paths in product development, manufacturing, or applied research, and demonstrated future executive and technical leadership potential. It is expected that there will be a blend of students who are sponsored by their company or institution and those who are self-sponsored and seeking to gain a concise and focused technical and professional education, developing them for significantly expanded responsibilities upon graduation and, ultimately, leadership positions.

As outlined in figure A-1, below, and Appendix I, there three (3) main pillars of the program, each of which comprises nine (9) credits hours:

1) Aerospace Science and Engineering – graduate courses in Aerospace Engineering and Science, focusing on vehicle and systems design, emerging technologies, digitalization, sustainability
2) Business Application –including courses in finance, strategy, aerospace economics, organizational leadership, negotiations, complex project management, innovation and design thinking; 6 of 9 credits will be offered by INSEAD
3) Aerospace Enterprise Integration – A blend of technical and business areas including a formal team-based Capstone project, Systems Engineering, via ISD 520, enhanced leadership skills, including business ethics, communication, presentations, advanced teaming skills, enterprise structure, sustainability

Each of the three pillars is designed to address one of the educational goals. 27 credit hours is deemed the optimal balance to fulfill degree requirements; it yields a targeted focus in each of the three key areas optimized to achieve the educational goals, and still allows full-time students to complete the degree within a single calendar year (though most students are expected to enroll in the program on a part-time basis). Most M.Eng. and competitive programs we studied are in the 27-30 credit range; an independent

market research firm, Apollidon Learning, assisted with marketing and product positioning research and also concluded that positioning the degree at 27 credits will be seen as a competitive advantage by online participants.

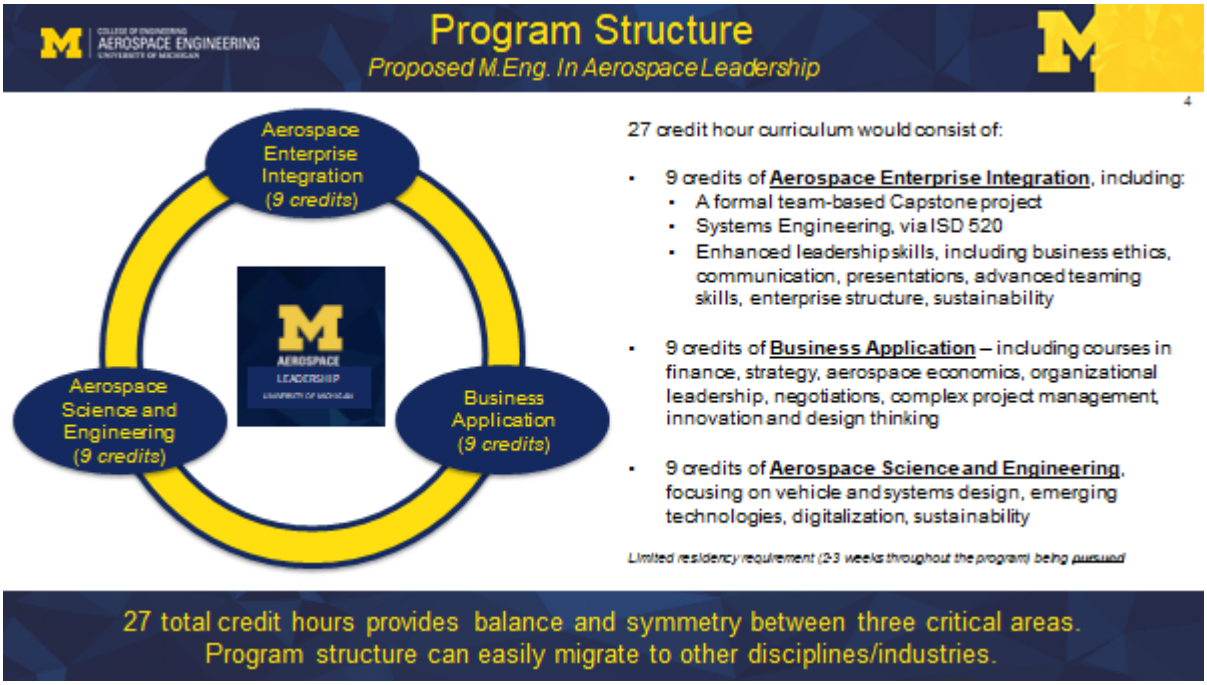


Figure A-1 – Three Pillars of the M.Eng. in Aerospace Leadership Program

Internal and external benchmarking suggest online programs with less than 30 credits are becoming far more common. Some examples include:

- UM courses which started as 30 credit hours and in Fall 2017 changed to 26:
  - M.Eng. in Construction Engineering and Management
  - M.Eng. in Structural Engineering
- UM courses approved for Fall 2020 as 26-credit programs:
  - M.Eng. in Electrical and Computer Engineering
  - M.Eng. in Smart Infrastructure Finance
- UC-Berkeley (sampling):
  - Data Science M.Eng. 27 credits
  - Cybersecurity M.Eng. 27 credits
  - Std. M.Eng. 25 credits

Most of the Program's courses will be asynchronous; synchronous instruction will reside mostly in the Aerospace Enterprise Integration pillar, which will include short-course teaching, guest lectures from distinguished and accomplished leaders from industry, lab, and academia, and a Capstone project led by a TBD adjunct Aerospace faculty member with significant industry experience.

The Program will have three in-person residency requirements (approximately three to five days each at three distinct times throughout the program) to foster organized team

Design/Build/Test/Fly events, the establishment of personal relationships, and student identification with their cohort, the University of Michigan, and INSEAD.

Residency will be composed of:

First week:	orientation, Design/Build/Test/Fly physical build, cohort building
Midpoint:	project coaching, in-person team collaboration, cohort building
Final week:	judged & graded team project presentations, graduation ceremony

B. Motivation

Motivation to pursue this offering "right here, right now" can be categorized into five (5) main drivers – the "FIVE WHYs:"

- Why Engineering Leadership and Professionalism?
- Why Online?
- Why Now?
- Why the University of Michigan and INSEAD?
- Why (start in) Aerospace Engineering?

Why Engineering Leadership and Professionalism?

Consistently and over time, a multitude of articles and other works have been written on the need to round out exceptional technical education with the 'essential' business skills required to translate technical achievements into real engineering solutions:

> Wulf & Fisher wrote, "*Today's student-engineers not only need to acquire the skills of their predecessors but many more, and in broader areas. As the world becomes more complex, engineers must appreciate more than ever the human dimensions of technology, have a grasp of the panoply of global issues, be sensitive to cultural diversity, and know how to communicate effectively*."[1]
>
> Felder, Woods, Stice, and Rugarcia wrote, "*Deficiencies in engineering education have been exhaustively enumerated in recent years. Engineering schools and professors have been told by countless panels and blue-ribbon commissions and, in the United States, by the Accreditation Board for Engineering and Technology that we must strengthen our coverage of fundamentals; teach more about "real-world" engineering design and operations, including quality management; cover more material in frontier areas of engineering; offer more and better instruction in both oral and written communication skills and teamwork skills; provide training in critical and creative thinking skills and problem-solving methods; produce graduates who are conversant with engineering ethics and the connections between technology and society; and reduce the number of hours in*

[1] *Issues in Science and Technology, Vol XVIII, No. 3, Spring 2002*

the engineering curriculum so that the average student can complete it in four years."[2]

S.P. Nichols and W.F. Weldon wrote, "*An engineer's conduct (as captured in professional codes of conduct) toward other engineers, toward employers, toward clients, and toward the public is an essential part of the life of a professional engineer, yet the education process and professional societies pay inadequate attention to the area. If one adopts Skooglund's definition of professional ethics (1) (how we agree to relate to one another), then the codes of professional conduct lay out a road map for professional relationships. As professionals, engineers need to internalize their codes and to realize that they have a personal stake in the application of codes as well as the process of developing the codes. Yet, most engineers view professional codes as static statements developed by "others" with little (or no) input from the individual engineer. Complicating the problem, questions of professionalism (such as ethics) are frequently viewed as topics outside the normal realm of engineering analysis and design. In reality, professional responsibility is an integral part of the engineering process.*" [3]

The National Society of Professional Engineers (NSPE) Code of Ethics states, "*Engineering is an important and learned profession. As members of this profession, engineers are expected to exhibit the highest standards of honesty and integrity. Engineering has a direct and vital impact on the quality of life for all people. Accordingly, the services provided by engineers require honesty, impartiality, fairness, and equity, and must be dedicated to the protection of the public health, safety, and welfare. Engineers must perform under a standard of professional behavior that requires adherence to the highest principles of ethical conduct.*"

Even as this issue has been highlighted for decades, very few, if any, R1 institutions have truly cracked the code of achieving such a balanced blend of engineering, business, and practical application, and as such this is an area ripe for a 'Leaders and Best' initiative.

Over the last year, these essential business skills have been infused at the undergraduate level in Aerospace Engineering at the University of Michigan, with strong feedback from students. It is being continued in a subsequent series of undergraduate courses integrating systems engineering principles, tools, and processes with leadership and professionalism teachings, into an advanced design-build-test-fly sequence.

The goal of the M.Eng. in Aerospace Leadership Program is to extend the model applied successfully at the undergraduate level into the graduate educational realm.

[2] *Chem. Engr. Education, 34(1), 26–39 (2000), cited from "The Future of Engineering Education: I. A Vision for a New Century." Chem. Engr. Education, in press.*
[3] *Professional Responsibility: The Role Of Engineering In Society, 1997*

Why Online?

Establishment and launch of another high-quality and credible online program will expand the University of Michigan's outreach and global presence, as it is envisioned that students from around the world in the major Aerospace multinationals will participate in this accelerated and exclusive program.

An online program such as this will provide significantly greater accessibility to non-traditional engineering students:

- Early-mid career
- Unable to relocate to Ann Arbor due to family or other obligations
- Working full-time in a critical job, and wanting to maintain their employment status while pursuing an advanced education in both technical and business skills

Why Now?

Rapidly-accelerating technology and process inventions for remote and online educational delivery have expanded significantly in the previous several years. While they will never replace traditional in-person educational experiences, these advances have rendered an online experience far better than what it was even just a few years ago.

Moreover, the major disruptions caused by COVID-19 have forced the hand of corporations, government agencies, private business, and academia alike to increase reliance on virtual education and communication.

> TeachOnline.CA writes, "*Blended and online learning are a feature of most strategic plans for colleges, universities and polytechnics. The plans have been given a new emphasis as the pandemic forced online learning everywhere.*"[4]

[4] *Teachonline.ca, A New Pedagogy is Emerging… and Online Learning is a Key Contributing Factor, August 4, 2020 (repeat)*

Why University of Michigan and INSEAD?

The University of Michigan Department of Aerospace Engineering is one of the nation's top programs, with its graduate program ranked at #4 and undergraduate program ranked at #5 in the 2021 U.S. News and World Report. Faculty are world-renowned and provide students access to cutting edge education and research, which will make the education highly valued, and the degree highly desirable.

INSEAD is the world's preeminent international business school and has campuses in Fontainebleau, France (main), Singapore, and Dubai. They were recently ranked #4 overall in the Global MBA Rankings by the Financial Times (trailing only Harvard, Wharton, and Stanford).

Why (Start In) Aerospace Engineering?

Aerospace Engineering is an engineering major which is also an industry, providing a relatively straightforward path to combine aerospace science and engineering teachings with aerospace-related business and enterprise teachings. Furthermore, the Department of Aerospace Engineering's Industrial Advisory Board has been promoting such a combination consistently, and thus will be a strong advocate in helping shape the program and facilitate its adoption in many of the member companies.

That said, it is still believed that, upon successful launch in Aerospace Engineering, application to other College of Engineering Departments is strongly desirable, either aligned with the Departments, or with specific industries.

C. Aerospace Engineering and College of Engineering Opportunities

The benefits to Aerospace Engineering are immediate and tangible. This program will enable the University of Michigan Aerospace Engineering Department to be a pioneer in offering an intensive, technical, business, and experiential learning program to a customer base which has been asking for it for years. It will provide access to a student base who otherwise would have to fulfill their needs locally (west coast, or southeast) or in other countries, and it is also expected to make the University of Michigan part of major aerospace companies' leadership development efforts.

Furthermore, it will provide UM Aerospace Engineering's research efforts expanded visibility to individuals (M.Eng. in Aerospace Leadership graduates) who are expected to be future leaders at their respective companies; as such, they will be key decision-makers relative to where their corporate research dollars go. A favorable experience at Michigan is expected to predispose them to invest here.
Benefits accruing to the College of Engineering will be:

- Revenue
- Development of an online model structure which can be easily applied in other CoE departments
- Potential recognition for being first in a new educational segment
- A catalyst for future Engineering and INSEAD collaborations

D. What Related Programs Exist?

While there are many top universities offering online Aerospace Engineering M.Eng. degrees, most of them are in conventional Aerospace Science and Engineering.

The proposed program targets a 'white space' in online graduate education (engineering and business blend) which is virtually unoccupied by major universities; thus the competition at present is very small. This yields a potential sustainable competitive advantage opportunity for the University of Michigan that few can match.

A market research survey was sourced to an external market research firm by Nexus and Aerospace Engineering. The study, performed by Apollidon Learning, was conducted between the dates of July 24th and September 4th, 2020 and included:

- Market acceptance
- Potential customers – domestic and international
- Competitive assessment
- "Where to Play, and How to Win"
- Final recommendation

Apollidon Learning concluded there is a fertile "white space," with strong market opportunity and potential for UM leadership. It also included recommendations for how to differentiate and win. More data are provided in Appendix I, and in a separate 108-page report which is available to CoE Curriculum Committee members upon request.

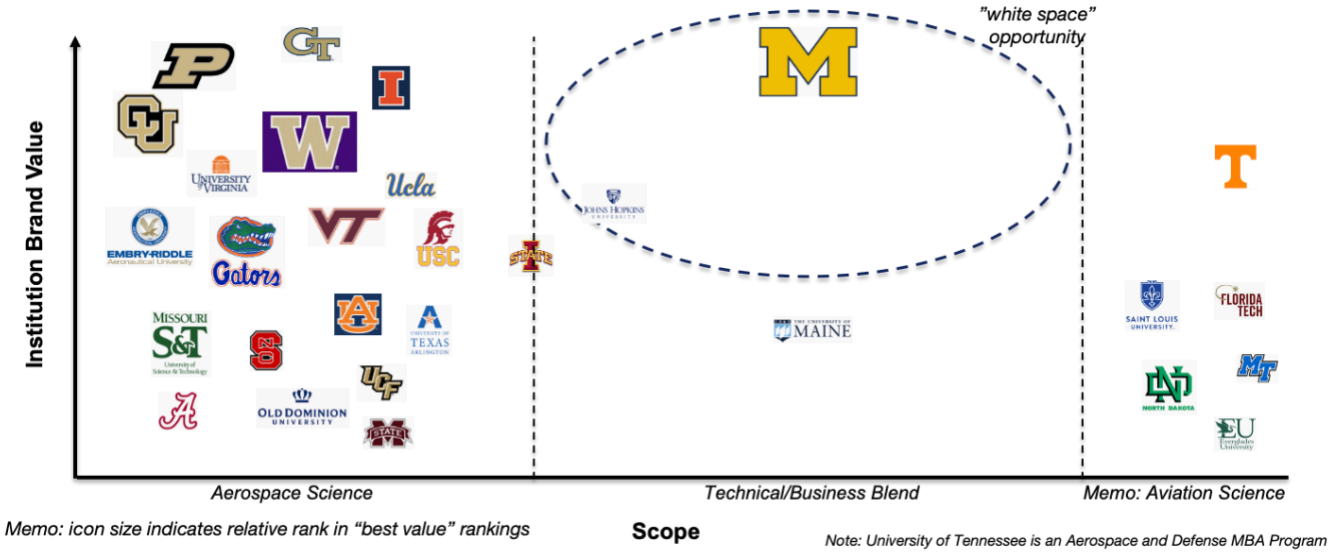


Figure B-1 – Product Positioning Map, Competition

E. Curriculum Design and Degree Requirements

The target audience for the M.Eng. in Aerospace Leadership degree is working engineers between 3-7 years into their careers who have demonstrated exceptional technical and engineering skills on the job and are pursuing leadership positions in technical operations. They are seeking a compact, impactful, and accelerated education in both advanced technical skills and essential business skills – but are, for a variety of reasons, (financial, career maintenance/advancement, family responsibilities, etc.) unable or unwilling to relocate to Ann Arbor.

Students will come from two basic sub-populations:

1) Those who have been identified by their companies (or lab, etc.) as future technical and business leaders, and in whom the company wishes to invest via sponsorship (tuition payment/subsidy)
2) Those who have self-identified as wanting a similar accelerated educational experience to advance their technical and business knowledge, and add valuable credentials to their portfolio, for potential career change

For the first couple of years, enrollment will be limited to ~15-25 students per year focusing on corporate-sponsored students, to control launch and growth. Market and Industrial Advisory Board feedback suggests a steady state of between 40 and 60 students per year in Aerospace Engineering, which could grow further if/when the program is expanded to other engineering disciplines.

As shown in Figure A-1, the 27-credit program is divided the following three (3) pillars:

1) Aerospace Science and Engineering

2) Business Application
3) Aerospace Enterprise Integration

Aerospace Science and Engineering

Requirements in this category are fulfilled by taking four (4) courses worth a total of nine (9) credits in Aerospace Science and Engineering:

- Students will pick from one of two tracks: Aeronautics and Astronautics.
    - They will take two (2) courses worth two (2) credits each (totalling 4 credits) in the areas of aerodynamics & propulsion, structures, and dynamics & controls.
- All students will be required to take a two (2) credit "Verification & Validation - Model Based Systems Engineering" course.
- Additionally, students will take one (1) course worth three (3) credits in systems & vehicles.

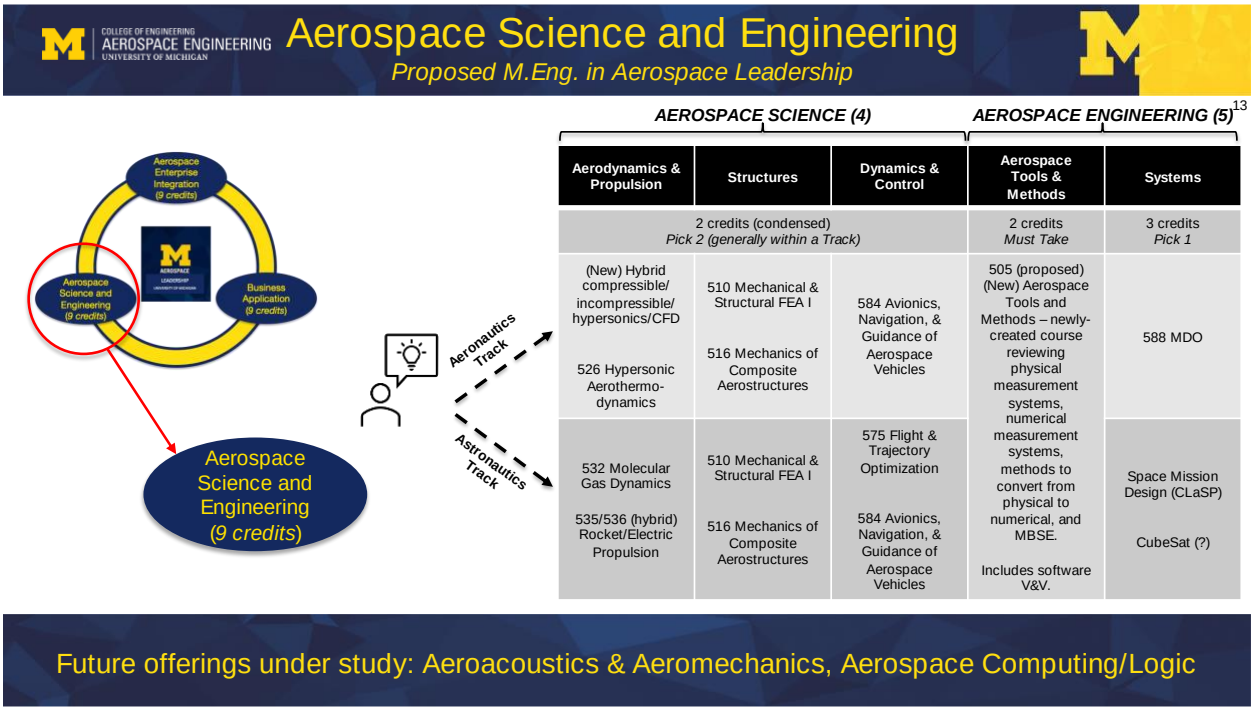


Figure C-1 – Aerospace Science and Engineering Courses

Courses will come from Aerospace Engineering and Climate and Space Sciences & Engineering (CLaSP). The engineering course menu will be a blend of:

- existing courses
- hybrids of existing courses, and
- all-new courses

… all converted to online asynchronous delivery by Aerospace Engineering and CLaSP faculty, working in conjunction with Nexus. These courses need to be "productionized"

into an online format– nominally a 6-9 month effort per course. They can and will be productionized in parallel, not in sequence.

New course or section numbers will be established for the online versions of these courses. Non-M.Eng. students could enroll in these courses, subject to course/professor and grader capacity.

Business Application
A total of nine (9) business application credits are required for the Program.

Requirements in this category are fulfilled by taking five (5) required "level 1" INSEAD courses and one (1) "level 2" elective course worth one (1) credit each (a total of 6 credits):

INSEAD Business Application Courses

Strategy & Finance	Financial Analysis for Non-Financial Managers	Building Digital Partnerships and Ecosystems
	Strategy in the Age of Digital Disruption	
Leadership	Developing Emerging Leaders	Strategic Negotiations
	Leading Organizations in Disruptive Times	
Critical Thinking	Innovation in the Age of Disruption	Design Thinking & Creativity for Business

The other three (3) credits in this area will consist of:

- Aerospace Economics (brand new course) -- which will introduce students to the macro- and micro-economics of the industry: how much an aircraft costs, how many do you need to run a fleet, how to optimize usage, profit, and how that translates down into the operational design and manufacturing decisions engineers make on a day-to-day basis. - 1.5 credits
- Project Management (via Center for Entrepreneurship) - 1.5 credits

Aerospace Enterprise Integration

This is the pillar which differentiates the offering through integration of systems engineering, 'essential' business and leadership skills, and a Capstone project. The structure of each is shown as follows:

- **Systems Engineering (3 credits):**
  - This requirement is fulfilled through the three (3) credit *ISD 520 – Introduction to Systems Engineering* course, which is already offered both online and live. ISD 520 is compulsory for all students, regardless of concentration.

- **Aerospace Leadership and Professionalism - AEROSP 500 (3 credits):**
  - This course will include mini-modules around 'essential' business skills – business and engineering ethics, complex project management, risk-based decision-making, communication, sustainability, strategy, large & complex enterprise management, sustainability, and corporate social responsibility (CSR). It will also include teaming best practices, including how to run remote operations, strategically pulling teams in-person when required, so that they can be managed most effectively on a remote basis.
  - This course will involve a blend of Professor of Practice-developed pedagogy and material from Aerospace Engineering, INSEAD, ISD, and the Center for Entrepreneurship, supplemented by the real-world experiences of distinguished industry leaders (astronauts, former Secretaries of military branches, corporate executives, etc.)
  - A CARF has been approved by the Aerospace Engineering curriculum committee in October of 2020. It has been routed through the College of Engineering and is fully approved.

- **Capstone Project (3 credits):**
  - This will be a cross-functional, nominally 3- 5-person, semester-long team project integrating key learnings from the curriculum, combined with the students' career interests.
  - In the case of students who are sponsored, project proposals from the sponsoring company will be clearly entertained. Furthermore, in this case, students and co-advisors can travel to sponsoring company operations for project presentations at the end of the program (in partial fulfillment of the 'residency' requirement). Standard NDA and IP agreements will be invoked where possible, consistent with how they are handled in the MDP program.
  - This course will be potentially advised by a new Professor of Practice/ Adjunct Faculty member with substantial industry experience.

F. General Program Requirements and Policies

Total credit hours, as outlined above, is 27. It is anticipated that most students will enroll on a part-time basis, and complete the program in 24 months. Students can, on an exception basis, request up to 36 months. *(Note: the first few cohorts will be required to enroll on a part-time basis, with potential expansion to a full-time option after the program reaches a steady state.)*

Graduate transfer credits will be allowed, provided the following criteria are met:

- They are from an accredited 4-year university which offers grad degree programs
- The credits were not counted in fulfillment of another degree (e.g. advanced degree in engineering or business, bachelor's degree, etc.)
- The petitioning student provides the institution name, course number, and syllabus – which will all be subject to the Program Director/Manager's approval

Students will typically take 4-6 credits per term, including spring/summer. Once begun, students will be expected to enroll in a minimum of one class each semester in order to maintain their enrollment status, or risk having to reapply. (This will be subject to gaining commitment from at least one affected faculty to teach spring/summer.)

G. Administration

The Program Director will be George Halow, Professor of Practice in Aerospace Engineering; the Program Manager is Amanda Winters from Aerospace Engineering. The Program Director and Program Manager will be responsible for all tactical implementation details to launch and manage the program.

Tony Waas, Aerospace Engineering Department Chair,will help set strategic direction for the program in conjunction and alignment with the CoE Associate Dean for Graduate and Professional Education (ADGPE), the Dean of the College of Engineering, and INSEAD.

Additionally, as referenced on page 1, two governing bodies will be formed:

Governing Body	Composition	Chair	Meeting Frequency
Internal Advisory Committee	CoE academic leaders and professors (see page 1)	Tony Waas (Aerospace Engineering Chair)	2x/year
External Advisory Board	Industry and government senior executives (see page 2)	Kevin Michaels (Aerospace Engineering IAB Chair)	1x/year

Figure G-1 – Aerospace Leadership Governing Bodies

These bodies will review, assess, and provide guidance on all academic matters, including current and future course offerings, program delivery and quality, degree conferral, and expansion to other departments within the CoE. The inputs will include

both quantitative and qualitative assessments of students, faculty, staff, and corporate partners, summarized and compiled into a formal annual report, which will also be provided to the ADGPE.

The full-time and dedicated Academic Program Manager, reporting to the Program Director, will:

- manage degree requirements
- serve as the main point-of-contact for students, corporate customers, and internal University of Michigan partners
- manage all operations, including marketing, financial performance and distributions, recruiting, and lessons learned/continuous improvement
- develop all relevant documentation and communications, including the reports going to the governing bodies and to the Deans of Engineering and INSEAD

Should future circumstances warrant the deletion of this program, the Aero department will manage the process.

H. Enrollment, Scheduling Plans, and Implementation

To ensure a smooth and seamless launch of this new program, the first two cohorts will commence with a limited number of students from select corporate partners. When 'steady state' is achieved (i.e. once the program has run for 1-2 years and demonstrated quality of educational delivery via to-be-developed metrics), the program will pursue public enrollment, and follow admissions deadlines and candidate vetting processes similar to other professional M.Eng. programs offered by the University of Michigan.

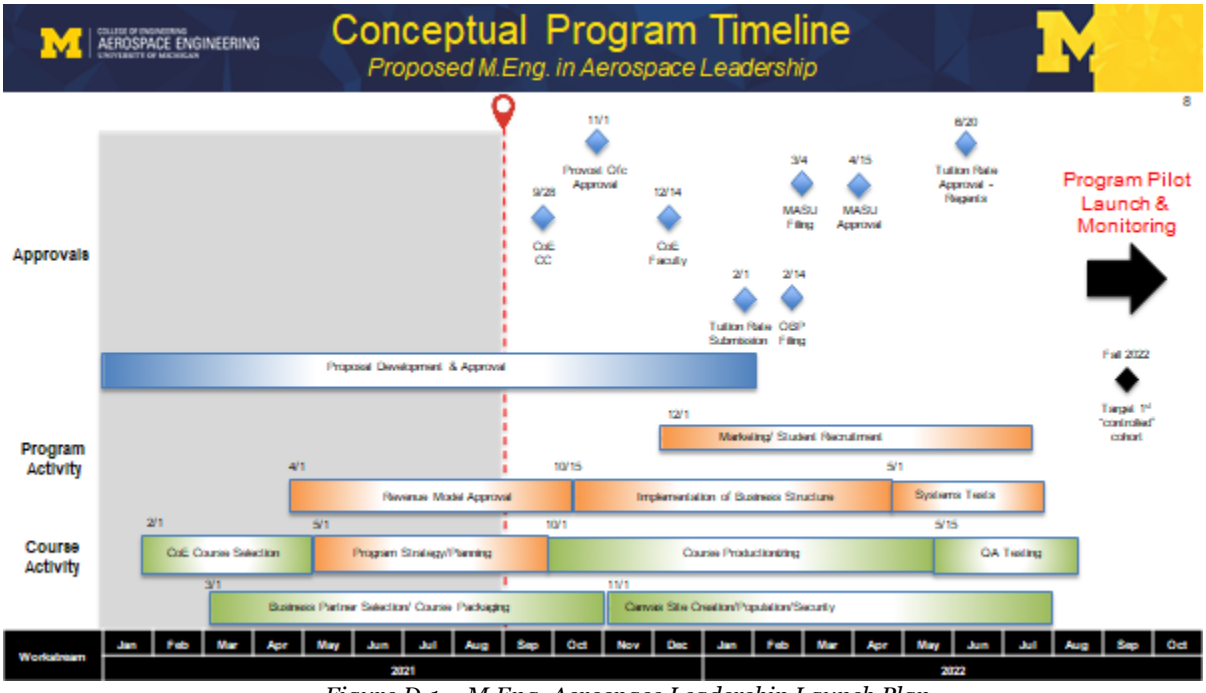


Figure D-1 – M.Eng. Aerospace Leadership Launch Plan

I. Library and Other Learning Resources

M.Eng. students will have the same access and privileges as University of Michigan residential graduate students.

J. Specialized facilities, Including External Sites as Required

None required

K. Diversity, Equity, and Inclusion

Diversity, Equity, and Inclusion will be a central theme in the curriculum, and will transcend the coursework into admissions, administration, and the overall degree experience.

Many efforts will be undertaken to make this a role model for inclusive programs:

- Between 1-3 partial and/or full scholarships will be pursued to enhance diversity in the program, with selection criteria following the Rackham Merit Fellowship (RMF) Program selection criteria. These scholarships will bear the name of the company sponsor as well as a historical figure in the Aerospace Enterprise – e.g. Tuskegee Airmen, Bessie Coleman, Amelia Earhart
- The 'Effective Teams' module will include teaching and exercises in recruiting, developing, and maintaining diverse teams. This is already being piloted in AEROSP 495, with preliminary positive feedback from student participants
- Guest lectures from senior leaders from historically underrepresented groups – not just to talk about diversity but also to talk about their experiences in core technical operations, serving as role models:
    - For the underrepresented students in the class, so they can see the art of the possible and learn from these distinguished practitioners
    - For all the students in the class, to paint a new face of Aerospace which is far more diverse than what has been portrayed historically
- Work with the Aerospace Graduate Student Advisory Committee (GSAC) on connecting graduate students from historically underrepresented demographics with existing GSAC resources, eventually migrating to custom programs with GSAC when the M.Eng. cohorts reach a critical mass (e.g. > 35 – 40 participants)
- Seek corporate donations for resources like adequate internet access, where the basic infrastructure exists, for economically challenged students to ensure they can access all M.Eng. program resources
- (After the cohorts grow to critical mass) establishment of subgroups and student identification groups within the M.Eng. Before that, we can also provide access to resources from existing groups within Aerospace Engineering: Women in Aeronautics and Astronautics (WAA), Black Students of Aerospace (BSA), and others.

APPENDICES

I. Externally-Contracted Market Research Summary
II. CARFs
    - AEROSP 501 – Aerospace Economics
    - AEROSP 502 – Capstone
    - AEROSP 505 – Aerospace Tools and Methods
III. Letters of Support
    - Aerospace Engineering
    - Associate Dean Graduate & Professional Education
    - INSEAD
    - Aerospace Engineering Industrial Advisory Board
    - Center for Entrepreneurship

Appendix I – Market Research Summary

An external market research firm, Apollidon, was contracted by Nexus and Aerospace Engineering to perform a market survey of the proposed degree offering, including:

- Market acceptance
- Potential customers – domestic and international
- Competitive assessment
- "Where to Play, and How to Win"
- Final recommendation

Key Takeaways

- Online master's programs are closing the gap with residency programs
- "Burgeoning" interest in engineering/business combinations
    - Very few competitors in the 50/50 split realm – competitive opportunity, and leapfrog with joint degree conferral
- This may be the precise time to develop online assets – to ride the wave of economic recovery with a fully-implemented and proven offering
    - Advanced education enrollment increases have historically followed economic crises by ~18 months
    - Although commercial aviation is particularly reeling from the pandemic, defense and space are less affected and may be prime for early partnerships and sponsorships
- A 27-credit program can be a positive attribute to potential applicants, as long as they see the educational mission and goals satisfied
- UM already has very strong interdisciplinary brand recognition; successful application of technology and customer experience (UX) will make the program 'transformational'
    - And well-placed to compete with its most formidable competitor, Johns Hopkins
        - Note JHU tuition is $45,950 but is single-unit degree conferral, with no Capstone project, and 100% online

Market Research Conclusions

- UM should proceed with the Program, and do so in a very decisive, convincing, and transformational manner:
    - Joint CoE (Aerospace) and Ross branding
    - Master key new technology and student service differentiators (UX)
    - Pursue "strategic partnerships" with one or more aerospace companies (steady enrollment, financial support)
    - Consider a more extensive residency component to better attract international students
    - Pursue the introduction of certificates and other newer forms of innovative delivery (without sacrificing UM Brand or IP) as an incentive to corporate partners, and a marketing tool to increase enrollment

Appendix II – New CARFs

AEROSP 501 – Aerospace Economics

Course Approval Request Form
Office of the Registrar, University of Michigan

LS&A Suite 5000
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

CHECK APPROPRIATE BOXES FOR ALL CHANGES

Action Requested
☒ New Course
☐ Modification of Existing Course
☐ Deletion of Existing Course

Date of Submission:10/18/2021
Effective Term: Fall 2022

☒	Course Offered ☒ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	REQUESTED LISTING
☒	Dept (Home): Subject: Catalog:	Dept (Home): Aerospace Engineering Subject: AEROSP Catalog: 501
☐	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number
☒	Course Title (full title)	Course Title (full title) Aerospace Economics
☐	Abbreviated Title (20 char)	Abbreviated Title (20 char) Aero Economics
☒	Course Description (Please limit to 50 words and attach separate sheet if necessary) Graduate course in informing optimal engineering decisions based upon product lifecycles and customer usage profiles. This course drills down into customer needs and how they're fulfilled by aerospace products, ultimate lifecycles of those products how they inform the best product decisions, and future considerations around technology, sustainability, and industry trends.	
☒	Full Term Credit Hours Undergraduate Min: Graduate Min: 1.50 Undergraduate Max: Graduate Max: 1.50	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☒	Course Credit Type Non-Rackham Graduate	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: AEROSP Catalog: 501

☒

Grading Basis
☒ Graded (A – E)
☐ Credit/No Credit
☐ Satisfactory/Unsatisfactory
☐ Pass/Fail
☐ Business Administration

Grading
☐ Not for Credit
☐ Not for Degree Credit
☐ Degree Credit Only

Add Consent
☐ Department Consent
☐ Instructor Consent
☐ No Consent

Drop Consent
☐ Department Consent
☐ Instructor Consent
☐ No Consent

	CURRENT LISTING	REQUESTED LISTING
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☒

Course Components
☒ Lecture
☐ Seminar
☐ Recitation
☐ Lab
☐ Discussion
☒ Independent Study

Graded Component
☒
☐
☐
☐
☐
☒

Terms Typically Offered (Please select only one)
Fall, Winter, Spring-Summer or [blank]

Instructor Name: TBD

Instructor Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED

Contact Person: George Halow Email: gfhalow@umich.edu Phone: 734-936-1462

Curriculum Committee: Date:

Dept Chair(s):
Home Department: Date:

Cross-Listed Department: Date:

Cross-Listed Department: Date:

Cross-Listed Department: Date:

AEROSP 502 – Aerospace Leadership Capstone

Course Approval Request Form

Office of the Registrar, University of Michigan

LS&A Suite 5000
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

CHECK APPROPRIATE BOXES FOR ALL CHANGES

Action Requested
☒ New Course
☐ Modification of Existing Course
☐ Deletion of Existing Course

Date of Submission:10/18/2021
Effective Term: Fall 2022

☒	Course Offered ☒ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	REQUESTED LISTING
☒	Dept (Home): Subject: Catalog:	Dept (Home): Aerospace Engineering Subject: AEROSP Catalog: 502
☐	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number
☒	Course Title (full title)	Course Title (full title) Aerospace Leadership Capstone
☒	Abbreviated Title (20 char)	Abbreviated Title (20 char) Aero Lead Capstone
☒	Course Description (Please limit to 50 words and attach separate sheet if necessary) Graduate Capstone course/ project where students work in teams of 4-5 to develop a comprehensive technology, product development, and business proposal, and apply all program learnings to the project. Students present to a panel of industry judges who grade the quality of the project, presentation, and use of the tools/methods.	
☒	Full Term Credit Hours Undergraduate Min: Graduate Min: 3.00 Undergraduate Max: Graduate Max: 3.00	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☒	Course Credit Type Non-Rackham Graduate	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: AEROSP Catalog: 502			
☒	Grading Basis ☒ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☐ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☐ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions
☒	Course Components ☒ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☒ Independent Study Graded Component ☒ ☐ ☐ ☐ ☐ ☒	Terms Typically Offered (Please select only one) Fall, Winter, Spring-Summer or [blank]
Instructor Name: George Halow		Instructor Title: Professor of Practice, Aerospace Engineering

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED

Contact Person: George Halow Email: gfhalow@umich.edu Phone: 734-936-1462

Curriculum Committee: Date:

Dept Chair(s):
Home Department: Date:

Cross-Listed Department: Date:

Cross-Listed Department: Date:

Cross-Listed Department: Date:

COLLEGE OF ENGINEERING
AEROSPACE ENGINEERING
UNIVERSITY OF MICHIGAN

AEROSP 505 – Engineering Tools & Methods

Course Approval Request Form

Office of the Registrar, University of Michigan

LS&A Suite 5000
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

CHECK APPROPRIATE BOXES FOR ALL CHANGES

Action Requested
☒ New Course
☐ Modification of Existing Course
☐ Deletion of Existing Course

Date of Submission:10/18/2021
Effective Term: Fall 2022

☒	Course Offered ☒ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☒	Dept (Home): Subject: Catalog:	Dept (Home): Aerospace Engineering Subject: AEROSP Catalog: 505
☒	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☒	Course Title (full title)	Course Title (full title) Engineering Tools & Methods
☒	Abbreviated Title (20 char)	Abbreviated Title (20 char) Engr Tools & Methods
☒	Course Description (Please limit to 50 words and attach separate sheet if necessary) A Model-Based Systems Engineering (MBSE) course covering physical and virtual engineering, emphasizing move from physical to virtual. Correlations between physical and virtual evaluations for different technologies and systems will be discussed. Formal requirements delivery through MBSE, and Six Sigma (6σ) tools/processes will drive understanding of MBSE model use and limitations.	
☒	Full Term Credit Hours Undergraduate Min: Graduate Min: 2.00 Undergraduate Max: Graduate Max: 2.00	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☒	Course Credit Type Non-Rackham Graduate	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: AEROSP Catalog: 505			
☒	Grading Basis ☒ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☐ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☐ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions
☒	Course Components ☒ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☐ Independent Study Graded Component ☒ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered (Please select only one) Fall, Winter, Spring-Summer or [blank]
	Instructor Name: George Halow	Instructor Title: Professor of Practice, Aerospace Engineering

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED

Contact Person: George Halow Email: gfhalow@umich.ed Phone: 734-936-1462

Curriculum Committee: _____ Date: _____

Dept Chair(s):
Home Department: _____ Date: _____

Cross-Listed Department: _____ Date: _____

Cross-Listed Department: _____ Date: _____

Cross-Listed Department: _____ Date: _____

Appendix III – Endorsements

Aerospace Engineering Department Chair

COLLEGE OF ENGINEERING
AEROSPACE ENGINEERING
UNIVERSITY OF MICHIGAN

ANTHONY M. WAAS
Richard A. Auhll Department Chair
Professor of Aerospace Engineering
Felix Pawlowski Collegiate Chair Professor

François-Xavier Bagnoud Building
1320 Beal Avenue
Ann Arbor, Michigan 48109-2140

T: 734 764-3388
F: 734 764-3350
awaas@umich.edu

November 5, 2021

To: College of Engineering Curriculum Committee

Subject: Requesting Approval of Proposed Aerospace Leadership Online M.Eng.

Aerospace Engineering is requesting approval for a new online degree program entitled Master of Engineering (M.Eng.) in Aerospace Leadership. This breakthrough proposal, which is a collaborative approach between Engineering and one of the world's top-ranked business schools, INSEAD, is strongly supported by an independent market research (Apollidon), the Aerospace Engineering Industrial Advisory Board (IAB), executives from multiple Aerospace companies, and the Dean of the College of Engineering. The College of Engineering has approved $2.1m to launch the program.

It is an intensive, online 27-credit degree program which combines two of the world's top institutions – Aerospace #5 in USNWR graduate program rankings, and INSEAD, perennially ranked in the global top 5 in graduate business (Financial Times surveys) – to provide a world-class curriculum integrating advanced technical education with 'essential business skills'. The program structure, and much of the content, can be migrated to other CoE Departments upon successful launch in Aerospace.

The externally-sourced market research, coupled with our own internal investigations, uncovered some significant competitive advantages:

- Combination of the powerful brands of Michigan Engineering and INSEAD – for a global reach matched by none other
- Equal splits of engineering and business
- Infusion of leadership and essential business skills, taught by industry practitioners, former astronauts, corporate executives, and governmental leaders
- An experiential learning component, manifested in a year-long Capstone project

Target launch is fall, 2022. To control launch timing and quality, we would not pursue open enrollment until year #2 or #3; year #1 will be a small cohort of corporate-sponsored students.

We sincerely appreciate the Curriculum Committee's careful consideration of this program, and look forward to a positive outcome which will allow us to launch this offering and capture an unclaimed but strongly desired space in online graduate education. Thank you.

Tony Waas

Associate Dean for Graduate & Professional Education

MICHIGAN ENGINEERING
UNIVERSITY OF MICHIGAN

Lola Eniola-Adefeso, Ph.D.
Associate Dean for Graduate & Professional Education
Professor of Chemical Engineering, Biomedical Engineering,
Macromolecular Science and Engineering

October 8, 2021

Dear Colleagues;

On behalf of the College of Engineering, I am pleased to submit this letter of support for the proposed online Master of Engineering (M.Eng.) in Aerospace Leadership. This interdisciplinary graduate degree program is to be offered through the College of Engineering (CoE) in collaboration with INSEAD.

The M.Eng. in Aerospace Leadership will focus on accelerated and balanced teachings in three core areas: Aerospace Science and Engineering; Business Application; and Aerospace Enterprise Integration. Diversity, equity, and inclusion will also be a central theme, transcending coursework into admissions, administration, and the overall degree program experience. Through support from Nexus, the College's home for online & professional education, this online program will align with the College's strategic educational mission to empower faculty innovation and increase its global reach and impact.

This proposed program will consist of 27 credit hours, which will be seen as a competitive advantage by online participants. Primarily asynchronous, this online degree program will be accessible to non-traditional engineering students who are unable to relocate to the Ann Arbor area to continue their education. Students will be high-performing engineers with 3-7 years of career experience who have demonstrated future executive and technical leadership potential. Considering the program's interdisciplinary nature, I am confident that this new degree program will attract high-quality graduate students.

By establishing this new online degree program in collaboration with INSEAD, we will expand our outreach and global presence. In addition to acting as a catalyst for future CoE and INSEAD collaborations, this program will help develop a framework for future online M.Eng. degree programs in other CoE departments.

It is our understanding that administration of this degree program will be maintained and managed by the Aerospace Engineering Department, including ongoing assessment of the program. A report on program outcomes will be provided to my office annually for CoE's ongoing assessment. Should the degree program warrant deletion at a future date, the Aerospace Engineering Department will be responsible for managing this process.

I look forward to the success of this exciting new program.

Sincerely,

Lola Eniola-Adefeso, Ph.D. (Fellow of AIMBE, BMES)
Associate Dean for Graduate & Professional Education
University Diversity and Social Transformation Professor of Chemical Engineering;
Biomedical Engineering; Macromolecular Science and Engineering
Director, Cell Adhesion and Drug Delivery Lab
Associate Director, NIH Cellular Biotechnology Training Grant
Deputy Editor for Science Advance

Robert H. Lurie Engineering Center, 1221 Beal Avenue
Ann Arbor, Michigan 48109-2102 USA

MAIN: 734 647-6851 F: 734 647-7075
lolaa@umich.edu

INSEAD

INSEAD The Business School for the World®

College of Engineering Curriculum Committee
University of Michigan
1221 Beal Ave.
Ann Arbor, MI 48109

Members of the Curriculum Committee:

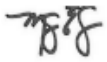
As Regional Director of the Americas for INSEAD Executive Education, I am writing in support of the Master of Engineering in Aerospace Leadership (MEAL) program. INSEAD is looking forward to contributing to the business and leadership portions of the program curriculum with executive-level courses from our Open Online Enrolment Program (OOP) portfolio. MEAL students will follow the business curriculum portion of the MEAL by completing selected courses from our OOP portfolio in the topics of Strategy, Finance, Leadership, Negotiations, and Innovation. As with all INSEAD OOP's, the course content is delivered with a focus on how the concepts are applied in a professional context and support the development of the participants' professional skills.

INSEAD will work with the University of Michigan to define the business leadership learning path for the MEAL students and the specific courses they will have to choose from. Our intent is to align the scheduling of the required courses, as much as is feasible, with the College of Engineering academic calendar and to be able to accommodate the number of students who wish to enrol.

INSEAD looks forward to partnering with University of Michigan College of Engineering in this capacity.

Please do not hesitate to contact me with any questions.

Sincerely,



Mary Carey
Regional Director, The Americas
INSEAD Executive Education

INSEAD San Francisco Hub for Business Innovation
224 Townsend St.
San Francisco, CA, 94107
United States of America
T +1 415-278-7808

www.insead.edu

Aerospace Engineering Industrial Advisory Board

COLLEGE OF ENGINEERING
AEROSPACE ENGINEERING
UNIVERSITY OF MICHIGAN

14 September 2021

Subject: Industrial Advisory Board Support for M.Eng. in Aerospace Leadership Proposal

Dear Curriculum Committee:

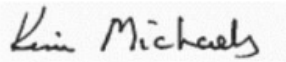
On behalf of the University of Michigan Aerospace Engineering Industrial Advisory Board, which is comprised of executives of major companies and government agencies, I would like to convey our unequivocal support for the M.Eng. in Aerospace Leadership degree program.

For many years, we as a Board have praised the University of Michigan College of Engineering for graduating the most technically sound engineers, but we have also consistently voiced concern that graduates lack the 'essential' business skills many organizations desire for leaders of their technical organizations. This problem is not new, and is not isolated to the University of Michigan, but we now see initiatives at both the undergraduate and graduate level – spearheaded by Professors Tony Waas and George Halow – to address this, and we are delighted by it.

This new degree proposal is exactly the kind of offering we believe will firmly differentiate the University of Michigan from a crowded space in online master's degrees and fill a void nobody else has been able to effectively fill up to this point. The partnership with INSEAD, Europe's highest ranking MBA program, elevates this to a global "best of the best" program with few peers. The IAB is ready to partner with the university, departments, faculty, and other industry sponsors to make the strong commitment required to deliver a successful launch, and then a repeatable, sustainable program.

Most of us IAB members are University of Michigan alumni (in my case I have a B.S.E. in Aerospace Engineering, and an MBA from Ross), and few things would make us prouder than seeing Michigan make the leap as a leader in this space and create a competitive advantage few others can match.

We sincerely hope the Curriculum Committee also sees the same opportunity and can make this opportunity a reality.



Kevin Michaels,
Chair – Michigan Aerospace Engineering Industrial Advisory Board
Managing Director, AeroDynamic Advisory

Center for Entrepreneurship

CENTER FOR ENTREPRENEURSHIP
UNIVERSITY OF MICHIGAN

College of Engineering Curriculum Committee
University of Michigan
1221 Beal Ave.
Ann Arbor, MI 48109

Members of the Curriculum Committee:

As Executive Director of the Center for Entrepreneurship (CFE), I am writing in support of this Master's of Engineering Leadership -- Aerospace proposal. This innovative program combines U-M's strengths in business and engineering education and offers new possibilities to engage with corporate partners and audiences.

In particular, the CFE looks forward to contributing to this program's curriculum an online 1.5-credit course on project management. Drawing on our long-standing course, ENTR 560: Project Management & Consulting, we are eager to collaborate in developing a customized version specific to the needs of this Master's in Leadership program, which will provide content regarding project launch, risk analysis and mitigation, decision models, change management, and more. As with the CFE's other courses, emphasis will be placed on experiential learning to provide students with professional skills that complement their technical expertise. Moreover, as it is integrated within the MEng curriculum, this course will equip students with project management tools that can be applied elsewhere in the program, including their capstone project. The CFE will oversee the development of this course curriculum, as well as the hiring of its instructor, and will ensure that sufficient seats are offered to accommodate the Master's of Engineering Leadership cohorts.

I believe this is a fruitful collaboration that draws upon the College's strengths to provide a unique experience for students. The CFE looks forward to partnering with the Aerospace department in this capacity. Please do not hesitate to contact me with any questions.

Sincerely,

Jonathan Fay, PhD
Dixon and Carol Doll Executive Director, Center for Entrepreneurship
Executive Director, NSF Midwest I-Corps Node

PRE-COVID POLICY

- Per UM-Ann Arbor departmental policy, CoE did not allow transfer credit for any ONLINE courses within these subject areas: IOE, CEE, CHEM, ECON, EECS, MECHENG, MATH, PHYSICS, and SPANISH. Foreign language courses focusing on language development were also not to be taken online. Prior to taking any course(s) online, students had to submit a TCAF (Transfer Credit Approval Form) and indicate on the form that they would be taking the course online, even if the course was already approved on either the CoE or LSA Equivalency Database.
- CoE students were limited to a maximum of 12 credits for online transfer coursework.

COVID POLICY

(March 2020 through April 2022)

- If a course in ENGINEERING, ECON, CHEM, PHYSICS or MATH has already been deemed equivalent in the database, then the course will transfer regardless of whether it is online or not. No need to fill out a TCAF. (see TCAF website)
- Credits earned in online courses during this period will not count towards the maximum of 12 online credit hours per student. (see Transfer Credit Information section of the Bulletin)

PROPOSED NEW POLICY (EFFECTIVE WINTER OR SPRING 2022)

- Eliminate the limit of 12 online transfer credits toward the degree
- Evaluate future transfer courses based on content and not format (i.e. stop disqualifying courses simply because they are online). Pre-approved courses that are taught online will be accepted without further evaluation.

RATIONALE FOR POLICY CHANGE

- The COVID-19 pandemic increased the number of online offerings from peer institutions, and that is not likely to change. The College ought to judge the course on the merit of its content and not on how the material was delivered.
- External transcripts typically do not indicate if a course was taken in person or online, so the CoE Credit Evaluation team does not know that a course was offered online unless a student completed a Transfer Credit Approval Form in advance.
- Transfer courses will continue to be evaluated by the department that owns the equivalent course to make sure they meet appropriate standards. Evaluators (typically an advisor or faculty member) will look at how classes are run and how testing happens. They will require examples of exams and assignments to make sure the online and in-person versions are equivalent.
- LSA passed a similar policy this year. Text from an email from Assistant Dean RaShonda Flint is pasted below for reference.
    - As we continue as a college to leverage what we learned from the pandemic and support new and continuing students transferring in coursework, I am excited to announce that the LSA Executive Committee has approved the LSA Curriculum Committee - Transfer Credit Subcommittee's recommendation that all

departments evaluate undergraduate courses for transfer using a consistent standard that focuses on review of course content and learning outcomes to award credit. This means that going forward, no department will be able to prohibit a course from transferring into U-M solely because it was taken online. This approval means that the following transfer credit policies will be permanently updated:

- All courses previously evaluated and currently approved for transfer credit in the Transfer Credit Equivalency (TCE) will continue to be accepted even if the course was taken with a different delivery method (i.e. online) and without any additional verification process for students
- All never evaluated courses will continue to be reviewed and approved by the appropriate department to ensure it includes key curricular content that is comparable (including the review of syllabi and exams), but no course should be summarily rejected solely because of the delivery method (i.e. online)
    - Note: Departments should begin to set courses directly equivalent in the TCE regardless of the course delivery method if determined to be equivalent otherwise

Fall 2021
Curriculum Committee Meeting

Online Transfer Credit Policy Proposal

Betsy Dodge, Kalyn Veal & Kerri Wakefield
(Registrar, Credit Evaluation, & Advising)

Proposal Summary

- Update online transfer credit policy to eliminate the limit of 12 online transfer credits toward the degree.
- Evaluate online transfer courses on the merit of their content and not on how the material was delivered (i.e. stop rejecting courses simply because they are taught online).

Pre-COVID Policy

- CoE did not allow transfer credit for any online courses within these subject areas: ENGINEERING, ECON, CHEM, PHYSICS or MATH. Prior to taking any course(s) online, students had to submit a TCAF (Transfer Credit Approval Form) indicating that they would be taking the course online, even if the course was already approved in the Transfer Credit Database.
- CoE students were limited to a maximum of 12 credits of online transfer coursework.

COVID Policy (March 2020-April 2022)

- If a course in ENGINEERING, ECON, CHEM, PHYSICS or MATH has already been deemed equivalent in the database, then the course will transfer regardless of whether it is online or not. No need to fill out a TCAF.
- Credits earned in online courses during this period will not count towards the maximum of 12 online transfer credit hours per student. (see Transfer Credit Information section of the Bulletin)

Proposed New Policy (Effective Winter or Spring 2022)

- ➔ Eliminate the limit of 12 online transfer credits toward the degree
- ➔ Evaluate future transfer courses based on content and not format (i.e. stop disqualifying courses simply because they are online). Pre-approved courses that are taught online will be accepted without further evaluation.

Rationale

- The COVID-19 pandemic increased the number of online offerings from peer institutions, and that is not likely to change.
- External transcripts typically do not indicate if a course was taken in person or online, so the CoE Credit Evaluation team does not know that a course was offered online unless a student completed a Transfer Credit Approval Form in advance.

Rationale

- Transfer courses will continue to be evaluated by the department that owns the equivalent course to make sure they meet appropriate standards. Evaluators (typically an advisor or faculty member) will look at how classes are run and how testing happens. They will require examples of exams and assignments to make sure the online and in-person versions are equivalent.
- LSA passed a similar policy this year.

Questions about the Online Transfer Credit Policy Proposal?

COLLEGE OF ENGINEERING
ROBOTICS INSTITUTE
UNIVERSITY OF MICHIGAN

05 September 2021

Dear CoE Curriculum Committee,

With this memo, I am requesting approval for the establishment of a Robotics Undergraduate Major conditioned on the faculty of the College of Engineering approving the establishment of a Robotics Department. Dean Alec Gallimore and ADAA Steve Ceccio anticipate a vote on the department question taking place during the F-21 semester.

Background

Robotics faculty have taken the opportunity of a new department to rethink how to meet the needs of the 21st Century for excellence in both equal opportunity and leading scholarship. To prepare a diverse group of students for the era of Information, AI, Data, and of course, Robotics–all domains where Linear Algebra is the *Lingua Franca*, Robotics introduced ROB 101 Computational Linear Algebra, which promptly won the Provost's Teaching Innovation Prize in its pilot semester. Innovations included: breaking the stranglehold of Calculus and associated AP credits, whose availability is often tied to one's Zip Code; and re-imagining the way mathematics is introduced to first-semester engineering undergrads, by integrating math with programming to allow engineering projects at the "scale of life" (building maps for robot navigation from LiDAR data; building a precipitation surface map inspired by Machine Learning, but based in least-squares and regression; and controlling a planar model of a Segway using optimization).

Values

The desire to design a curriculum that favors a student's success being determined by their intellectual ability and drive instead of where one attended high school is being extended to the entire UG Curriculum. The success of ROB 101 in building a bridge with Morehouse is being extended to create a Distributed Teaching Collaborative with MSIs, with explicit planning in course offerings to include remote participation of students from HBCUs, collaborating with them on a summer camp for HS Students run through Morehouse, and placing course content online...not just the videos of the lectures, but the actual course notes and supporting material.

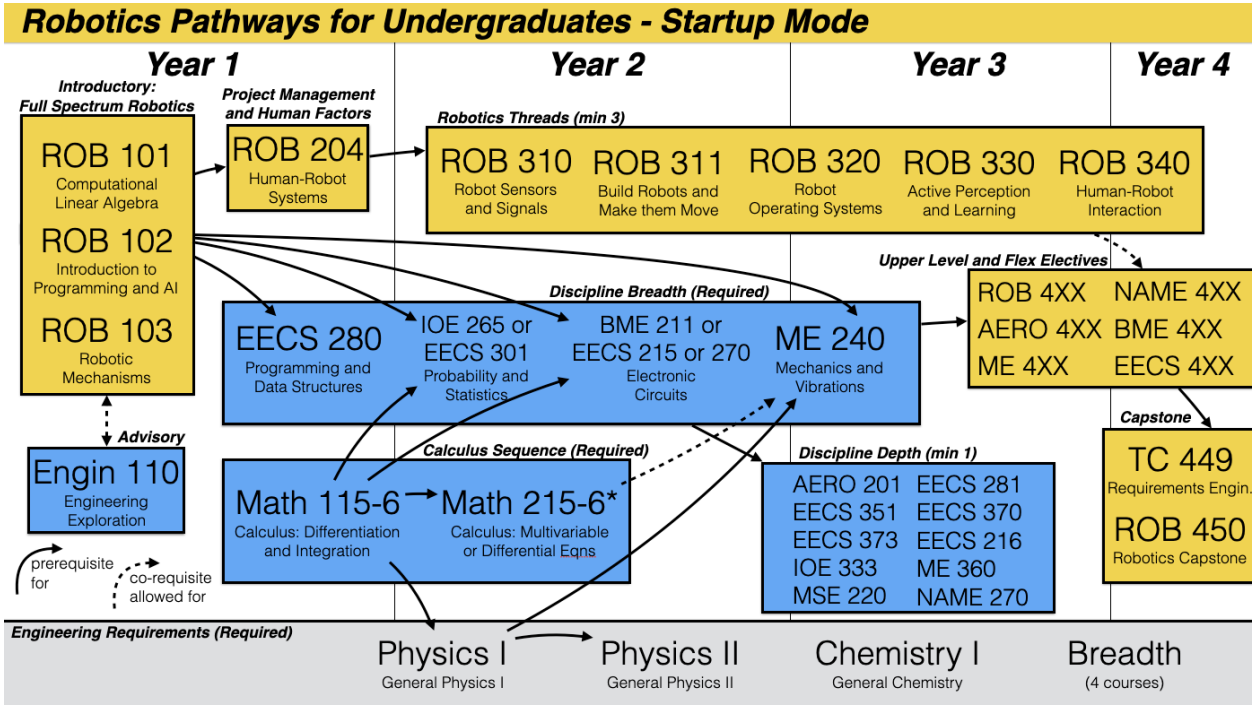
The values of Michigan Robotics foster a culture of compassion to address today's social injustice. Michigan Robotics aims to cultivate the leaders and the best with consideration of personal development at all career stages, innovation in undergraduate and graduate programs, and engagement with partners in K-12 education, minority serving institutions, industry, and the public sector. Robotics faculty actively participate in demographic-specific conferences and venues (e.g., NSBE, SWE, SHPE) to engage students who may not have otherwise considered

applying to Michigan. *100% of current faculty and staff who hold appointments in the Robotics Institute have completed the Change it Up! To Stop Anti-Black Racism training module*. I and other Robotics faculty have developed an 11th grade course in cooperation with Detroit metro schools and, as cited above, founded *Distributed Teaching Collaboratives* with HBCUs, which are specifically designed to realize the potential of underserved communities to contribute to--and participate in--- the field of robotics. Robotics has also invited Ford Motor Company to assist with these efforts, which has generated goodwill all around.

Defining the Discipline of Robotics

The Michigan Robotics Undergraduate Program has been formed for innovation that builds on the foundation of Michigan Engineering and furthers the ethos of ``Robotics With Respect." Michigan Robotics aims to meet undergraduate intellectual needs emerging in the 21st Century by inspiring students from their first day on campus and cultivating equal opportunities for a diverse world. Indicators of student interest, both formal and anecdotal, show high interest among undergraduates for a Robotics major. Our society has a growing and unmet demand for people skilled in robotics, as well as artificial intelligence. Michigan is well poised to lead the evolution of higher education to meet these challenges, affect positive systemic change, and prepare future generations for a highly dynamic innovation ecosystem.

A schematic of the Robotics Pathways curricular graph.



Michigan Engineering has a unique opportunity to further its global leadership by defining robotics as a core academic discipline. An undergraduate curriculum of a discipline organizes and disseminates its intellectual foundation. Our aim is to accommodate the learning needs of

students who strive to be roboticists, and longer term, ``X+Robotics'' students in existing engineering degree programs who want exposure to robotics. This proposal is only for a major or double major and does not address a minor in Robotics because we currently lack the faculty bandwidth to tackle that important group of students. An undergraduate major creates an acculturation of students into a discipline and its academic climate. The Michigan Robotics Undergraduate Program aims to realize a just, diverse, equitable, and inclusive environment for scholars at all stages of learning, with graduates who improve the human condition throughout their careers.

The Robotics Pathways are organized around the study of embodied autonomous systems that perceive, reason, and act in the physical world. The Robotics Pathways are organized to complement many intersecting disciplines across the academy. The Robotics Pathways have a significant intersection with artificial intelligence and its study of autonomous reasoning systems that make inferences from data and prior knowledge. It is the unforgiving factors of uncertainty in the real world - ambiguity in sensing, nondeterminism in actions, messiness of the natural world - that distinguishes robotics and its academic demands.

The Robotics Pathways introduces two innovations into Michigan Engineering curricular offerings: the Full Spectrum Robotics Introduction and the Robotics Threads curricular and advising model. These innovations are complemented by exposure to the disciplinary breadth of engineering at the intersection of robotics. Students are educated in the core topics of electronics, mechanisms, computation, probability and statistics, and human-robot interaction.

The Full Spectrum Robotics Introduction

The Full Spectrum Robotics Introduction provides a flexible and immersive introductory experience into the discipline of robotics. Aligned with the philosophy of Michigan Engineering for first-year education, this introductory experience exposes students to the foundations for modern engineering through the lens of autonomous navigation for mobile robots:

- computational fluency for expressing ideas through coding (coding is believing)
- maker and shop competency for realizing systems that can move in the physical world
- linear algebra as a compelling catalyst into higher mathematics
- human and social dynamics for working in teams to develop solutions for people

In startup mode, the Full Spectrum Robotics Introduction courses are taking shape through courses that have been piloted or are in current development. Robotics 101 (Computational Linear Algebra) is suited to complement traditional and more theoretical linear algebra courses (such as Math 214 and 217) while giving students sufficient preparation for intermediate and upper level courses in Engineering. Robotics 101 provides the mathematical concepts for representing spatial systems, such as for 3D mapping, and large linear systems of equations, such as for bipedal control. Similar in aims to Engineering 101, Robotics 102 (Introduction to AI and Programming) provides an introductory experience to computational thinking and programming in preparation for data structures courses. Robotics 102 conceptualizes

computing as graph and graph algorithms that are grounded in various approaches to path planning for mobile robots. In alignment with sections of Engineering 100, Robotics 103 (Robotic Mechanisms) is an introductory real-world design experience to build and control a mobile robot inspired by warehouse robots used in supply chain logistics. Robotics 103 familiarizes students with shop facilities for making physical systems and introduces students to low-level controls and embedded programming. Robotics 204 (Human-Robot Systems) introduces students to the human dimensions of robotics, including introducing human-information processing models to support robotic system design and real-world integration. Robotics 204 presents both the usability of robotics and the structure and workflow for human-centered design to inform project management. Robotics 204 serves as the gateway course into the Robotics Threads, the intermediate level for Robotics majors and eventually, minors.

The structure for the first year in the Robotics program is quite different from the usual first year structure, and there is a concern among some departments that students will be pressured into deciding to pursue Robotics as a major before they come to campus. However, the ROB 100-level sequence is an experiment that is attempting to revise how first year engineering students are taught regardless of discipline. The Robotics Institute is working closely with the ADUE to ensure that the courses meet the goals of the first year program as currently implemented. For instance, ROB 103 (102) meets similar learning objectives as ENGR 100 (101), and is thus an acceptable substitute. ROB 101 is addressing inequities in how we recruit and train engineers, and breaks the stranglehold AP Calculus has on success in majoring in STEM fields. Furthermore, Students who take ENGR 100, ENGR 101, and Math 214 will be accepted into ROB 204, such that not taking the ROB 100-level sequence does not preclude students from majoring in Robotics.

The Robotics Threads Advising and Curricular Model

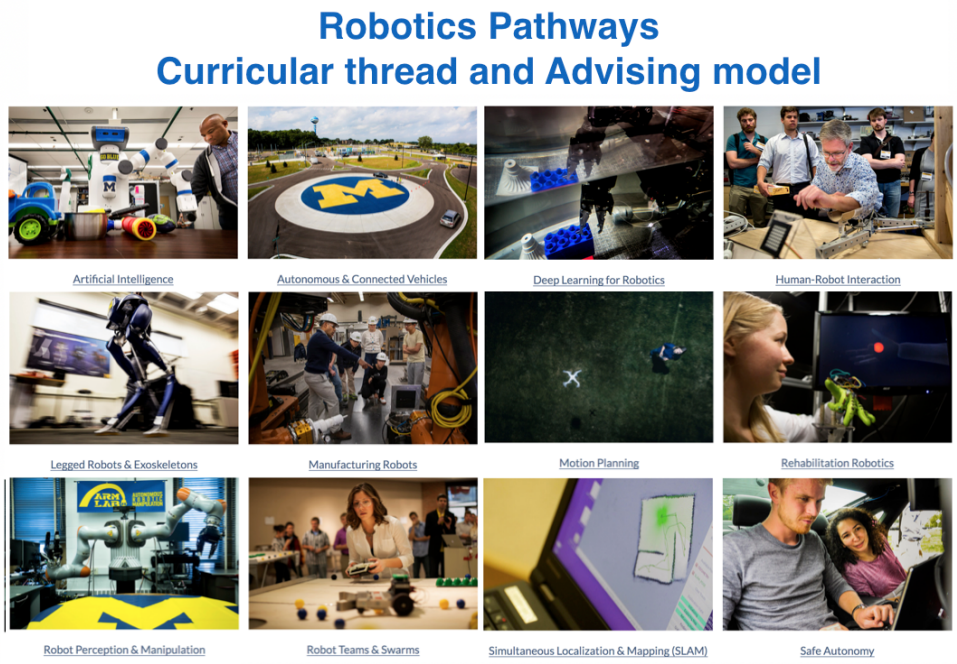
The Robotics Threads is the curricular and advising model for deeper study into the discipline of robotics for both majors and minors. Among the broad reach of robotics, there are a core set of competencies that lead to many different paths for emerging roboticists and intersections with other disciplines. Further, advising that connects with students and their interests as individuals can combat one of the largest factors preventing diversity: isolation. Towards this end, the Robotics Threads start from the premise of presenting students with possible professional pathways beyond their completion of a major in Robotics. Students can envision what pathway is best for them, and work with their advisor to find a degree-satisfying course plan that will help them achieve their goals. To meet the diverse range of robotics pathways, we have identified the Robotics Threads Intermediate Level courses as core topics in robotics that can be flexibly selected to provide a solid foundation for the discipline of robotics. These courses provide firm grounding in a subset of the core dimensions of robotics that can be built upon for further exploration in upper level courses as well as continued learning into other core areas of robotics.

Advising tailored to the interest of the student

Start by identifying their career goals

Thread topical courses together to meet their goals

Refine as their interests develop



Sincerely,

Jessy W. Grizzle
Director of Robotics
Jerry W. and Carol L. Levin Professor of Engineering
Elmer G. Gilbert Distinguished University Professor of Engineering
Professor of Electrical Engineering and Computer Science
Professor of Mechanical Engineering (Courtesy Appointment).

Proposal for the Establishment of an Undergraduate Robotics Degree Program at the University of Michigan College of Engineering

Rationale

The academy needs to keep pace with the growing demand for jobs, technology, and innovation: The national and global technology landscape is shifting, and U-M is poised to meet this challenge. The US Bureau of Labor Statistics recently reported that the annual demand for qualified robotics professionals grew by over 13% in 2018 alone. In addition, up to 80% of US industrial employers are facing difficulties filling vacancies for highly skilled technical professionals, including robotics, computer vision, artificial intelligence, and motion control. These statistics are underscored by a growing market. The global industrial and service robotics markets are expected to grow by over 20% year over year (CAGR), reaching a total market of $310B by 2025—the writing is on the wall. The confluence of a gap in skilled workers and a growing market demonstrates the need to rethink technical higher education. That is, a new program is needed that i) provides interdisciplinary training in robotics curated to meet current and future technology demands of the robotics workplace, and ii) provides a college major, a clear designation of skills that will enable graduates to compete for the most promising and highly skilled jobs.

Students are searching for universities that offer robotics undergraduate majors and minors: There is an explosion of interest in robotics-related activities from young people of all ages, and a robotics department will draw these students. Middle and high school students interested in robotics have historically been unable to learn the desired technical content in school, and have instead turned to afterschool programs. FIRST Robotics—a league where teams compete with custom-built robots completing predefined tasks—was developed to meet this growing need. Over the past decade, the number of FIRST Robotics teams has grown by over 40x to over 40,000 teams, including 630 in Michigan. A similar program, VEX Robotics, has expanded to over 50 countries over the same period. These programs have a direct and meaningful impact on participating students. A recent study found that over 95% of students participating in VEX Robotics desired to learn more about robotics and engineering in their future education, including about a third of female participants. While the programs are

impressive, they represent a groundswell of interest from younger generations. These students have already demonstrated the lengths they will go to study robotics by pursuing these experiences in their free time outside conventional education. Without a clear and strong emphasis on robotics—namely, a robotics department with an undergraduate major—U-M may struggle to attract these promising students.

Demand at Michigan for Robotics UG Education: Market research shows that as many as 40 percent of current students expressed interest in a Michigan Robotics major or minor, while 25 percent of students who were accepted to Michigan but ultimately enrolled elsewhere indicated that they might have decided differently if Michigan currently offered a Robotics degree program. On one level, this underscores the need, even the urgency, for launching a full undergraduate Robotics curriculum. It also points to some important decisions the College and department will have to make if demand is as high or higher than projected, including the possible need to cap enrollment in a way that is equitable, meeting Robotics' and Engineering's commitment to diversity.

Curriculum and Degree Requirements

Below is a proposed set of course requirements for a Major in Robotics at the University of Michigan in accordance with the Core Requirements for Undergraduate Programs in the College of Engineering.

Michigan Robotics Undergraduate Program Requirements for Majors

Major Declaration Requirements

To declare a major in Robotics, a student must be a College of Engineering student and:

1. Have completed at least one full term at UM Ann Arbor
2. Have an overall UM GPA of 2.0 or better in courses taken at the UM Ann Arbor campus and be in good standing
3. Have completed or earned credit by exam or transfer for at least one course in each of these categories:
    a. Introductory Linear Algebra (e.g. Robotics 101 or Math 214)
    b. Introductory Calculus (e.g. Math 115, 116 or 156)
    c. Calculus-based physics lectures (e.g. Physics 140 or 160)
    d. Required introductory Engineering (~~Robotics 103 or~~ Engineering 100, and Robotics 102 or Engineering 101)
    e. Teamwork in Robotics: ROB 204* *Human-Robot Systems*

College of Engineering Core Program Requirements

1. Full Spectrum Robotics Introduction
    a. Introduction to Engineering: ROB 103 *Robotics Mechanisms* or Engineering 100

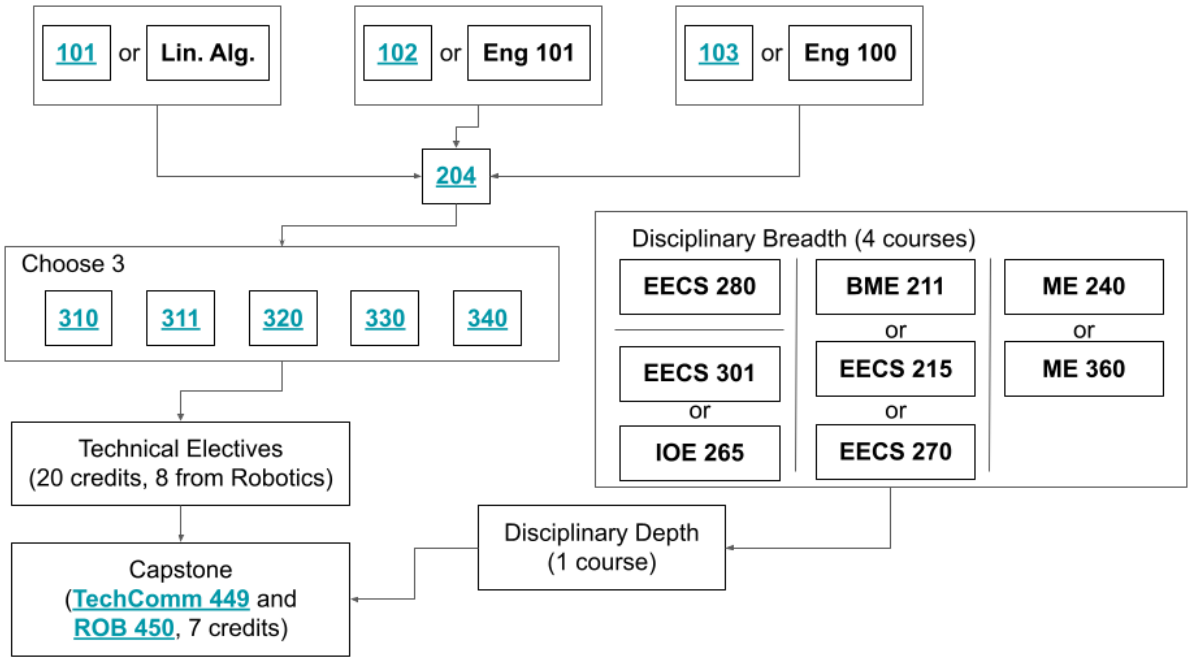
   b. Computational Thinking: ROB 102 *Introduction to AI and Programming* or Engineering 101 or introductory programming equivalent)
   c. Linear Algebra: ROB 101 *Computational Linear Algebra* or Math 214 or Math 217 or Math 417 or Math 419
2. Calculus requirements
   a. Introductory Calculus: Math 115 or Math 120 (AP); and Math 116 or Math 121 (AP)
   b. Intermediate Calculus: Math 215 or Math 216
3. Physics 140/141 and Physics 240/241
4. Chemistry 130 and 125/126*
5. Intellectual Breadth (16 credits) (as specified by the College of Engineering Core Requirements Bulletin - https://bulletin.engin.umich.edu/ug-ed/reqs/#subnav-11)
6. General Electives (15 credits)
   a. 15 credits are "required"; CoE degrees require 128 total credits, and more or fewer GE credits may be needed to achieve this total depending on individual factors in a student's record.

Robotics in Engineering Program Requirements

1. Teamwork in Robotics: ROB 204 *Human-Robot Systems*
2. Robotics Core: at least three of the following courses:
   a. ROB 310 *Robot Sensors and Signals*
   b. ROB 311 *Build Robots and Make Them Move*
   c. ROB 320 *Robot Operating Systems*
   d. ROB 330 *Localization, Mapping, and Navigation*
   e. ROB 340 *Human-Robot Interaction*
3. Discipline Breadth: at least one approved course from all of the following areas:
   a. Data Structures and Programming: EECS 280
   b. Probability, Statistics, and Visualization: IOE 265 or EECS 301
   c. Electronics and Circuits: EECS 215 or EECS 270 or BME 211
   d. Kinematics and Dynamics: ME 240 or ME 360
   e. Technical Communications: TCHNCLCM 340* *Technical Communication for Project Teams in Robotics*
4. Discipline Depth: one course from the following list (or approved by the Robotics Undergraduate Committee), such as IOE 333, AERO 201, EECS 373, NAME 270, EECS 281, EECS 370, EECS 216, EECS 351, MSE 220
5. Technical Electives: a minimum of 20 credit hours, with a minimum 8 credit hours from the approved list of Upper Level Robotics Courses and 300-level courses not counted for the Robotics Core requirement
6. Major Design: ROB 450* *Robotics Capstone* and TCHNCLCM 449* *Advanced Technical Communication for Robotics*

* to be developed and approved as part of the Robotics Capstone experience

a. Robotics Major Curricular Graph



b. Sample Course Schedule for a Major in Robotics

This sample course schedule has in mind a Robotics Major that is oriented towards computing and autonomous robots. Similar sample course schedules can be realized for Robotics Majors oriented towards mechanical systems, electrical systems, aerial robotics, autonomous underwater systems, human factors, project management, and more.

	Credit Hours	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Subjects required by all programs	(55 hours)								
Robotics 101 or Math 214[1]	4	**4**							
Engineering 100 or Robotics 103	4	**4**							
Engineering 101 or Robotics 102	4		**4**						
Mathematics 115 and 116	8		**4**	**4**					

[1] Or satisfying linear algebra course

Mathematics 215 or 216	4				**4**				
Physics 140 and Lab 141	5				**5**				
Physics 240 and Lab 241	5						**5**		
Chemistry 125/126/130 or 210/211	5							**5**	
Intellectual Breadth	16	**4**	**4**	**4**		**4**			
Program Subjects	(16 hours)								
Robotics 204	4		**4**						
Robotics 310	4								
Robotics 311	4						**4**		
Robotics 320	4				**4**				
Robotics 330	4					**4**			
Robotics 340	4								
Disciplinary Breadth	(16 hours)								
EECS 280 - Data Structures	4			**4**					
IOE 265 - Probability and Stat	3					**3**			
EECS 215 or 270 or BME 211	4			**4**					
ME 240 or 360	4					**4**			
TCHNCLCM 340*	1					**1**			
Disciplinary Depth	(4 hours)								
EECS 281	4				**4**				
Major Design Experience	(6 hours)								
Robotics 450 or EECS 467	4								**4**
TechComm 495*	2								**2**
Technical Electives	(20 hours)								
Upper Level Robotics Electives	12						**4**	**4**	**4**

Flexible Technical Electives	10						**3**	**4**	**3**
General Electives	(9 hours)	**3**						**3**	**3**
Total	128	**15**	**16**	**16**	**17**	**16**	**16**	**16**	**16**

c. List to be Approved Upper Level Robotics Courses

Upper Level Electives	
Signals and Sensors	
ROB 410	*Advanced Sensors*
ROB 412	*Neurorobotics*
Actuation and Motion	
ROB 411	*Robot Controls*
ROB 413	*Legged Locomotion*
ROB 415	*Multi-Robot Systems*
ROB 416	*Robot Dynamics and Simulation*
Reasoning and Autonomy	
ROB 420	*Mobile Manipulation and Semantic Robotics*
ROB 421	*Optimal Robotics*
ROB 422	*Algorithmic Robotics*
ROB 423	*Autonomous Vehicles*
Perception and Learning	
ROB 430	*Probabilistic Robotics*
ROB 431	*Robot Learning*
ROB 432	*3D Robot Perception*
Users and Interaction	
ROB 440	*Human-Robot Collab*
ROB 441	*Physical HRI*
ROB 442	*Ethics AI & Robotics*
Robustness and Exploration	
ROB 470	*Experimental UAS*
ROB 471	*Marine Robotics*
ROB 472	*Space Robotics*

Projects and Design	
ROB 413	*Bioinspired Robotics*
ROB 464	*Hands-on Robotics*
Capstone	
TCHNCLCM 449	*Requirements Engin*
ROB 450	*Robotics Capstone*

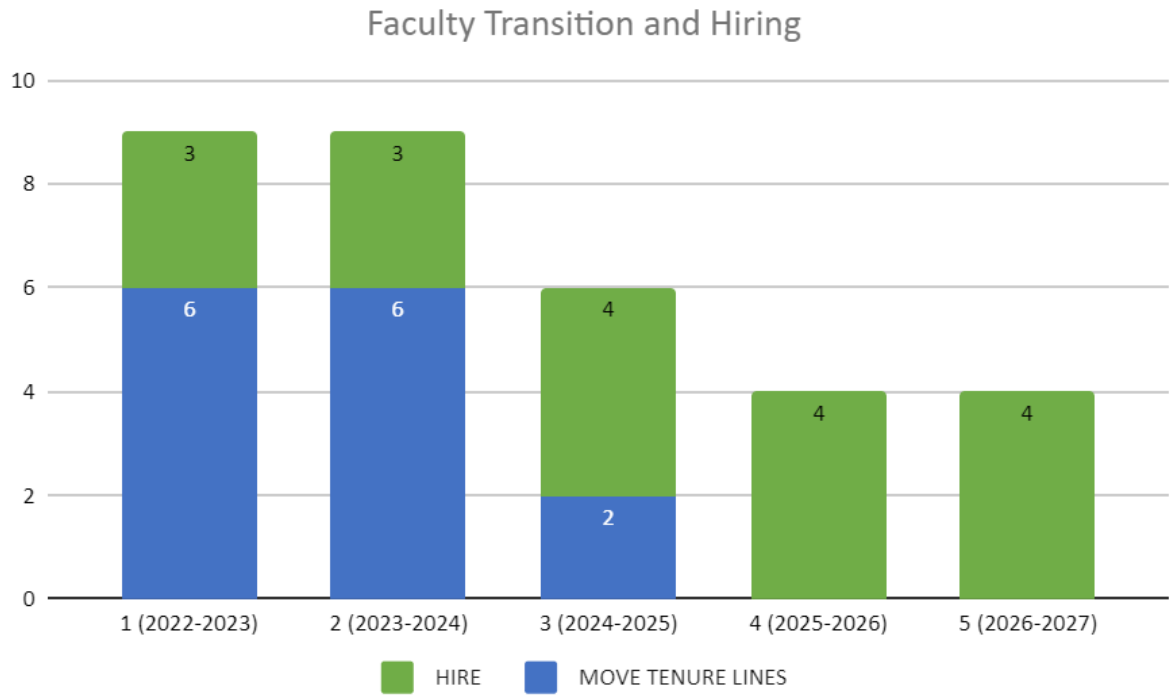
Faculty Resources

The Michigan Robotics Institute currently comprises an interdisciplinary group of 27 core faculty that span 12 departments, coupled with 42 affiliate faculty that contribute to the breadth and excellence of research. Robotics faculty research expenditures continue to show significant growth, outpacing the addition of new faculty. Indeed, over the past five years, research expenditures have increased from $5.6M to $16.0M, nearly tripling despite the addition of only five faculty members (~20% new faculty). The Institute emphasizes 'Full Spectrum Robotics,' with a broad array of faculty research interests, including human-robot interaction, legged and rehab robotics, artificial intelligence, autonomous and connected vehicles, dexterous manipulation, among many other areas.

The Institute offers a Graduate Program in Robotics with both MS and PhD degrees. Graduate students first matriculated in Fall 2014, and the program currently includes 158 students (87 MS and 71 PhD). Since its inception, applications have risen to over 1,000 in 2020. Michigan Robotics is currently engaged in the development of an undergraduate program and *Robotics Pathways for Undergraduates* curricular model that would lead to a major in robotics.

When (if) the Robotics Department is launched, there will be somewhere between 12 and 15 CoE T/TT faculty who will transfer tenure to the new department and we have two lecturers. The existing departments are insisting that the faculty transition in a phased manner. In addition, the College will provide hiring slots.

The table below shows the planned transitions of tenure slots and the hiring of new faculty. We may need to call on transferring faculty to teach Robotics UG courses before they transfer tenure and all of their research dollars to Robotics. This is under negotiation with the Office of the ADAA. Input from the CoE Curriculum Committee is welcome.



Admissions Requirements and Projected Enrollment

Enrollment: Market analysis and surveys contained in the “Proposal to Create a Robotics Department in the College of Engineering” suggest an undergraduate enrollment of 435 as the lower end. These sources all point toward a very high degree of student interest. In fact, as many as 40 percent of current students who responded to the survey expressed interest in a Michigan Robotics major or minor, while 25 percent of respondents who enrolled elsewhere indicated that they might have decided differently if Michigan currently offered these degree programs. Based on a conservative interpretation of these results, we estimate that 10% of incoming freshmen will declare Robotics. Assuming no attrition, no incoming transfers, and 4-year graduation rates, the department will enroll 435 ugrads in steady state. Of course, this enrollment level needs to be achieved over time. Figure 1.1.1. shows the proposed enrollment in the initial five-year ramp-up period.

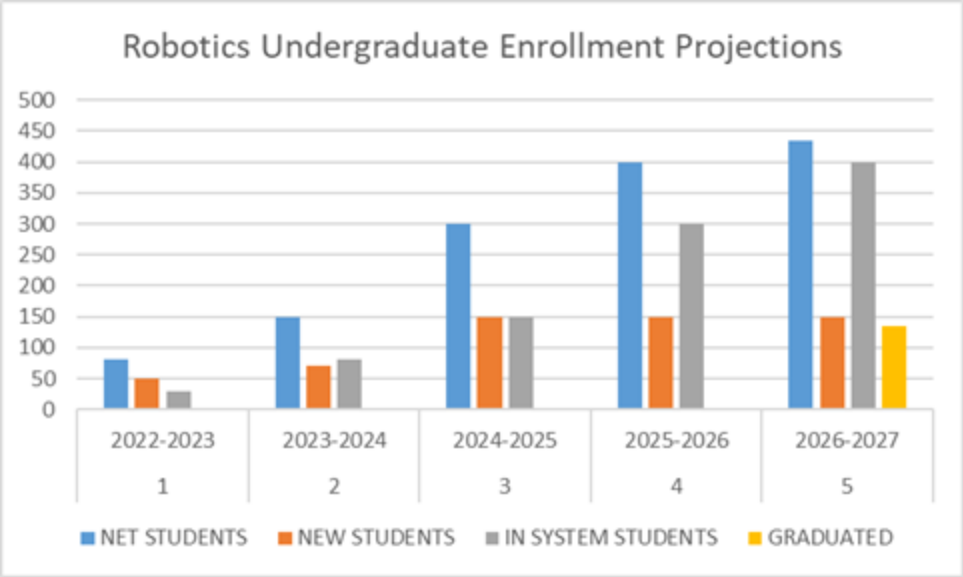


Figure 1.1.1.: Bar chart showing the proposed ramp-up of undergraduate student enrollment. Net students is the sum of new and in-system students less the number of graduated students.

Undergraduate Enrollment Control Mechanism The higher-end prediction potential majors cited in the market analysis would overwhelm the new department. Therefore, the Robotics department is aware that it must work with the Office of the ADUE to develop a fair and equitable mechanism to limit the enrollment in the initial five year period. When Biomedical Engineering first became a department, it limited its undergraduate enrollment by imposing a minimum GPA for declaring students. However, it is well-known that GPA is not necessarily an objective measure of academic success and is instead strongly correlated with demographic and socioeconomic factors. This is in direct contradiction with the goal of the new department to reform academic norms and culture. Another approach to limit the number of students is by creating a holistic review process to declare. No process currently exists for this at the department level, and such a process could be time-consuming for the fledgling department. A less onerous process, but one that may be less satisfying for students, would be a lottery system. Either of these processes, and perhaps others, should be considered carefully prior to implementation.

Admissions Requirements: These were given earlier in the document: **Major Declaration Requirements**

Program Assessment

Six-year Undergraduate Program Review

In concert with the planned Robotics Department, the Robotics Undergraduate Program is proposed to be reviewed every six years. This program review will consist of an internal review and an external review, each of which will produce evaluation reports that are submitted to the College of Engineering. The internal review will be done by a committee of selected faculty to summarize the current state of the Robotics Undergraduate Program and evaluate its strengths, weaknesses, and opportunities. This internal review will be followed by an external review performed by esteemed individuals in the field of robotics. It is expected that at least one member of this committee will also be a member of our standing Diversity Advisory Board. The report generated from this external review will be submitted to the College of Engineering.

Diversity Advisory Board

We wish to propose a group of highly distinguished, accomplished, and committed individuals from academe, industry, and a government lab to meet with us annually. Their combined expertise will serve us well for constructing and evolving a curriculum that is inclusive, fair, technically sound, meets the needs of professional practice as well as leading graduate programs, and could potentially be adopted by other departments and universities. *We have included the CoE Associate Dean of Undergraduate Education to provide advice for socializing our ideas at the 100-level with all of engineering at Michigan*.

Nancy M. Amato, Abel Bliss Professor and Head, Department of Computer Science, University of Illinois, Urbana-Champaign. *Role*: Providing advice on inclusive practices for women and minorities in STEM. Assessing adoption for UIUC.

Susan M. Lord, Professor and Chair of Integrated Engineering, Professor of EE, University of San Diego. *Role*: Providing expert advice on gender and diversity in engineering and how to operate a highly successful NSF RED proposal.

Monica Anderson, Associate Professor of Computer Science, University of Alabama, Researcher in Robotics. *Role*: Providing advice, best practices and effectiveness for mentoring of underrepresented minorities and women in robotics and computer science. She will bring her expertise for broadening participation from her work on the leadership of the NSF BPC-funded Institute for African-American Mentoring in Computing Sciences iAAMCS that serves as a national resource for all African-American computer science students and faculty.

Melanie Moses, Professor, Department of Computer Science, Secondary Appointment, Department of Biology, University of New Mexico. External Faculty member of the Santa Fe Institute. *Role*: Providing insights into effective methods for challenge problems and engagement strategies to reach underrepresented groups. She will bring her expertise from founding highly influential broadening participation programs, as **the** originator of CSforAll, which is now a national movement, and the NASA Swarmathon, a multi-robot exploration

competition that has had spirited participation from tribal colleges and Minority Serving Institutions.

Craig Stephens, PhD, Director: Controls & Automated Systems, Ford Motor Company. *Role*: Preparing students to enter the Robotics-AI workforce with a BSE degree in robotics. He will build on Michigan's unique Public-Private relationship that provides Ford an on-campus site for direct collaboration with Michigan faculty.

Michael Wolf, PhD, Principal Robotics Technologist and Group Supervisor, Maritime & Multi-Agent Autonomy, JPL. *Role*: Preparing students to enter the Robotics-AI workforce with a BSE degree in robotics.

Joanna Millunchick, Associate Dean for Undergraduate Education, Professor Materials Science and Engineering, Arthur F. Thurnau Professor, Bicentennial Professor, Academic Director of MSTEM Engineering Academy, College of Engineering, University of Michigan. *Role*: Leading the revision of calculus to combine Math 115 (Calc I) and Math 116 (Calc II) into a single course (she commissioned the report). Advocating for dissemination of our first-semester math course throughout the College of Engineering or the flexibility to choose among a set of courses to meet the math requirements.

Longitudinal Student Surveys

The Robotics Undergraduate Program firmly believes that wise student feedback comes longitudinally with time and perspective. As such, we will conduct annual surveys of the group of individuals that have enrolled in a Michigan Robotics course at any period of time. In addition to current students and dedicated roboticists, this group surveyed includes alumni, students that may have considered robotics but took a different path, and engineering students whose studies overlap with the Robotics. These surveys will be designed to gather information about student satisfaction, ideas for potential improvements and innovations, and program effectiveness in the professional outcomes longitudinally.

Accreditation

The Robotics Undergraduate Program is not planning in the short term to become accredited by bodies such as the Accreditation Board for Engineering and Technology, Inc. It is expected that the Robotics Undergraduate Program will lead in the formation of robotics as an academic discipline. As such, Michigan Robotics is planning to lead in the definition of standards for accreditation of robotics academic programs as the discipline takes shape over time.

Mitigation Plans and Responsibility for Program Deletion

The proposed degree program will go hand and hand with the creation of the new department. We are unaware of existing guidelines for the deletion of a department, which we believe, is the unique path leading to deletion of the proposed undergraduate major. If our assumptions are false, we will work with you on creating a plan for shutting down the degree.

We would be happy to have a sunset clause.

Requirements for Funding, Space, and Equipment

Funding and Equipment: The parameters to build a complete budget for the new department, a major in Robotics, equipment for labs, and a model for attributing GSIs and IAs that is more generous than the existing one in CoE, are included in the "Proposal to Create a Robotics Department in the College of Engineering". If the CoE Curriculum Committee has concerns over budget matters, we suggest working with the office of Deborah Mero and RPM https://rpm.engin.umich.edu/finance-budget/.

Space: The Ford Motor Company Robotics Building is a four-story, $75 million, 134,000-square-foot complex situated on North Campus. Its first three floors hold custom U-M research labs for robots that fly, walk, roll and augment the human body—as well as classrooms, offices and makerspaces. Through a unique agreement, the fourth floor houses Ford's first robotics and mobility research lab on a university campus, as well as 100 Ford researchers and engineers.

FRB Research Lab Space (as of 06/02/21)

- 23,647 sq ft
- Assigned PI's: 19, though two seem to be on semi-permanent leave
- Could support an additional ~7 to 9 PI's (given a 750 sq ft average per PI).

FRB Instructional Labs
There are 2 adjacent instructional labs (FMCRB 2010 + 2020) with a capacity of 32 students each (total of 64 students). In the Maker Space, the Student Team area is being configured to support 24 students per lab section.

We will be short on lab space for the new degree program. The 56 seat classroom FMCRB 1050 is directly across the hallway from the Robotics Institute's Electronics Laboratory. We will seek to schedule the lab sessions for ROB 310 Robot Electronics in FMCRB 1050, and wheel in carts with electronics equipment as needed. When soldering needs to be done, students can use the 6 snorkels in the Electronics Laboratory. Otherwise, the furniture in the room is fine for a lab experience.

Joanna M. Millunchick • Associate Dean for Undergraduate Education

September 2, 2021

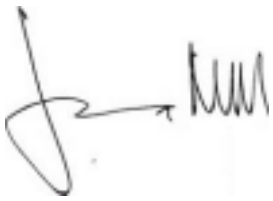
Dear College of Engineering Curriculum Committee,

I strongly endorse the planned undergraduate major in Robotics proposed by the Robotics Institute. In my capacity as Associate Dean for Undergraduate Education, I followed Robotics' progress in designing innovative first year courses. The approach that Robotics uses is to center student engagement so that they may apply theory to practice very directly. Also, they intentionally chose topics that are accessible to students regardless of their background, thus enhancing inclusivity.

I chaired the Robotics Planning Committee since January 2021 that submitted a master plan for the design and launch of a successful Robotics Department to Dean Alec Gallimore and Associate Dean for Academic Affairs, Steve Ceccio.

The proposal for an undergraduate degree in Robotics submitted by the Robotics Institute meets the high standards established by our existing departments. I strongly believe that the College has a unique opportunity to not only lead in Robotics research, but also to define the very discipline of Robotics itself.

Sincerely,



Joanna M. Millunchick
Associate Dean for Undergraduate Education

Robert H. Lurie Engineering Center OFFICE: (734) 647-7150 1221 Beal Avenue aduemillunchick@umich.edu Ann Arbor, Michigan 48109-2102

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-14
Effective Term: Winter 2023

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Robotics Subject: ROB Catalog: 310
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Robot Sensors and Signals
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Sensors & Signals
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Covers practical analog and digital electronics for robotics. Students will: prototype, test, and debug various analog and digital circuits; interface a microcontroller to external circuits; learn to design and prototype circuit boards; interpret data recorded from physical circuits. An exploration of circuits and embedded systems that supports integrated robotic design.	
☑	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: Undergraduate Max: 4 Graduate Max:	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student	
☑	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits: 0	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

	Grading Basis	Add Consent	Drop Consent
☑	☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	☐ Department Consent ☐ Instructor Consent ☑ No Consent	☐ Department Consent ☐ Instructor Consent ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) ROB 101 (Computational Linear Algebra) ROB 103 (Robotic Mechanisms)
☑	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) ROB 204 and (EECS 215 or BME 211) Minimum grade requirement: C-
☐	Credit Exclusions	Credit Exclusions

	Course Components	Graded Component	Terms Typically Offered
☑	☑ Lecture ☐ Seminar ☐ Recitation ☑ Lab ☐ Discussion ☐ Independent Study	☐ ☐ ☐ ☑ ☐ ☐	☐ Fall ☑ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Peter Gaskell	Cognizant Faculty Member Title: Lecturer IV

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Christina Hollis Email: crhollis@umich.edu Phone: 734-763-2869

CoE Curriculum Committee Representative:		Print:	Date:
CoE Curriculum Committee Chair:		Print:	Date:
Home Department Chair:	Jessy Grizzle	Print: Jessy Grizzle	Date: 10-14-2021
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Covers practical analog and digital electronics for robotics. Students will: prototype, test, and debug various analog and digital circuits; interface a microcontroller to external circuits; learn to design and prototype circuit boards; interpret data recorded from physical circuits. An exploration of circuits and embedded systems that supports integrated robotic design.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 2
Contact hours (recitation)	Contact hours (recitation) 0
Contact hours (lab)	Contact hours (lab) 4

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
Elective course for Robotics majors interested in physical construction of robots.

Special resources of facilities required for this course:
Availability of a CAEN Lab
Lab space to perform electronic measurements
Workshop space to build electronics

Supporting statement:
Assessment:
50% — 10 short group lab reports: filling in tables, plotting data, and answering questions about the results. This is done mostly in the lab and is due before the next week's lab session, should not be much out of lab work other than maybe formatting and labeling axes.

20% — 4 short individual quizzes or homeworks each covering 2 weeks worth of lab material. The final 2 weeks of lab projects are more building stuff, so not much knowledge that is testable in quiz format.

5% — Final group project proposal: this is where we grade the planning aspects of the group project and the thoughtfulness of the ideas

20% — Final group project presentation, this will be a demo of the circuit and poster presentation

5% — participation

Schedule (14 weeks total)

Week	Topics
Week 1	voltage, current, & power Kirchoff's law RLC circuits in time domain
Week 2	Impedance RLC circuits in frequency domain
Week 3	Op Amps Gain Feedback
Week 4	PN Junctions Diodes LEDs Photovoltaics
Week 5	Transistors Transistor amplifiers Voltage regulators Power supplies Batteries
Week 6	Survey of sensors AVR/ARM microcontrollers
Week 7	Binary / Hexadecimal Boolean Logic Logic gates
Week 8	Flip-flops Higher level logic (counters, adders, registers, multiplexers)
Week 9	Analog vs. Digital signal representation Analog to Digital conversion
Week 10	Serial communication RF communication
Week 11	Printed circuit board technologies CAD/CAM for electronic circuits
Week 12	Datasheet literacy Soldering Practical electronic components

Week 13	Societal impacts of sensors and systems, including issues of privacy, bias in data collection/mining, equitability of access
Week 14	Wrap-up Project presentations

++
Labs:

LAB 1: Resistors, Voltage & Current
Equipment: Power Supply, DMM, Breadboard

LAB 2: Time & Frequency response of various RLC circuits:
Equipment: Function generator, Oscilloscope, Breadboard
Students will place components on a breadboard and for each circuit:

1. measure the time constant by driving the circuit with a square wave
2. manually sweep a function generator while measuring the peak voltage of a sine wave on an oscilloscope
3. log all data in a log book.
4. plot the data for the lab report
5. answer questions based on the material.

LAB 3: Op amps, Noise, Active Filters, Differential signals:
active summing (add noise module signal to AC signal)
active filter (Sallen-Key topology)
current sense differential amplifier
3 op amp instrumentation amp
noise rejection and wheatstone bridge

LAB 4: Diodes & Photosensors & FET Amplifiers:
Students will place components on a breadboard and apply signals while making electrical measurements and logging the data in a log book. They will plot the data for the lab report and answer questions based on the material.

1. voltage drop of Diodes / LEDs
2. FET inverting amplifier
3. Measure brightness of LED with Photovoltaic or Photodiode

LAB 5: Microprocessor, ADC & DAC
toggle LED with I/O pin, charlieplexing
measure an analog voltage and print to terminal
1 bit DAC with PWM and RC filter
pseudo RMS measurement of AC waveform with rectifier/filter

LAB 6: Logic Gates, Flip-flops, Schmitt trigger

AND, OR, INV, and XOR from NAND gates
3-Bit adder with logic gates

LAB 7: Quadrature decoder to counter with FFs

LAB 8: Serial communication
Parallel ADC + Shift register + clock -> microcontroller
Interface to a digital sensor to capture data…

LAB 9: RF Communications
Interface to NRF24L01 module
Measure transmission distance

LAB 10: PCB Design/Solder/Build lab
create a simple circuit schematic and layout on a PCB
Mill it on the PCB mill
Solder it
Test it works

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-14
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Robotics Subject: ROB Catalog: 311
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) How to Build Robots and Make Them Move
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) How to Make Robots
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) ROB311 introduces the fundamentals of mechanical design, control, fabrication, actuation, instrumentation, and computer interfaces required to realize robotic systems. Students will learn to analyze/simulate rigid body kinematics, kinetics, and dynamics, as well as assess the impedance properties of their designs. 'Hands-on' skills will be emphasized in addition to theoretical concepts.	
☑	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: Undergraduate Max: 4 Graduate Max:	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student	
☑	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits: 0	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) ME 240 and/or 360, ROB 310
☑	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) ROB 204 Minimum grade requirement: C-
☑	Credit Exclusions	Credit Exclusions None

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☑ Lab ☐ Discussion ☐ Independent Study	Graded Component ☐ ☐ ☐ ☑ ☐ ☐	Terms Typically Offered ☑ Fall ☐ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Elliott Rouse	Cognizant Faculty Member Title: Assistant Professor

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Christina Hollis Email: crhollis@umich.edu Phone: 734-763-2869

CoE Curriculum Committee Representative:		Print:	Date:
CoE Curriculum Committee Chair:		Print:	Date:
Home Department Chair:	Jessy Grizzle	Print: Jessy Grizzle	Date: 10/14/2021
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description ROB311 introduces the fundamentals of mechanical design, control, fabrication, actuation, instrumentation, and computer interfaces required to realize robotic systems. Students will learn to analyze/simulate rigid body kinematics, kinetics, and dynamics, as well as assess the impedance properties of their designs. 'Hands-on' skills will be emphasized in addition to theoretical concepts.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture):
Contact hours (recitation)	Contact hours (recitation) 0
Contact hours (lab)	Contact hours (lab) 3

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
The objective of Robotics 311 is to introduce emerging roboticists to the tools that enable rapid design, prototyping, and control of robotic systems; in addition, the overarching goal of the course is conveniently obtained from the course title: "How to build robots and make them move." The course material will be delivered in a lecture setting, with one lecture per week dedicated to group projects. The goal of the projects will be to showcase the lecture content (e.g. the sensing, acting, and reasoning sections of the lecture material).

The course is intended to combine theory and practice. The lecture components of the class will include theoretical contributions in modeling, Lagrangian & Newton-Euler dynamics, and control, while the practical components will focus on CAD, manufacturing, and electrical hardware. Robotics 311 is arranged in this way to show how the theoretical and practical combined can create opportunities greater than the sum of their parts. Following the completion of this course, students should be able to:

Recognize a challenge that could be solved with a robotic system
Design a robotic system to solve the challenge
Manufacturer the robotic system
Test the robotic system for completion of the task
Lecture components will be taught broadly (tools to solve broad problems), where more 'application-specific' questions will be addressed with individual groups / group projects.

Special resources of facilities required for this course:

If there are any additional special resources or facilities required for this course, enter them here.

Ideally, this course would have the ‘hands on’ lecture in the large lecture hall in 1st floor FRB.

Supporting statement:
This course provides an important contribution to the students that will graduate with an undergraduate degree from U-M Robotics; namely, the tools to interact with the physical world. In addition to being well trained in the theoretical and computational aspects of Robotics, this course ensures our students have the pathway to also learn how that theoretical understanding can be used to impact the world around them. Robotics 311 is a key component of our Y2 - Y3 ‘Robotics Threads,’ where students have the ability to curate the type of roboticist they want to be. Courses in the Robotics Threads range from electronics and robot building to perception and human-robot interaction. Since students take a minimum of three, they are able to semi-specialize in an area of robotics.

Assessment: Robotics 311 will use several mechanisms to gauge students’ knowledge. The course will have ~7 technical homework assignments (i.e. paper and pencil style problems), in addition to a midterm exam. The student projects will be used in lieu of a final exam. Students will be graded on the ability of their project to complete the objective(s) set forth in the beginning of the term during project selection. Projects will be graded during demonstration / presentations that occur during the last two lecture periods. Our approach to assessment is based on the course’s objectives of teaching a combination of hands-on skill and theoretical skills.

Schedule (14 weeks total)

	Topics	Notes	Activities
Week 1	• Course overview • Basic effort and flow review • Rigid body dynamics • Lagrangian / Newton-Euler	Introduction Intro to modeling systems	Form groups and select group projects.
Week 2	• Rigid body dynamics cont. • Forward and inverse dynamics	Intro to modeling systems	Analyze system from group project
Week 3	• Brushed motors • Torque-speed / current-voltage • Basic brushless motor overview	Actuation	Determine actuation method for group project and simulate
Week 4	• Pneumatic systems • Basic transmission types and equations • Efficiency & thermal analysis	Actuation	Determine desired transmission ratio
Week 5	• Power supply considerations • PWM • Regeneration • CAD intro	Actuation	Begin sketching design concepts
Week 6	• Basic Solidworks • 3D Printers • Laser cutters	Rapid prototyping	Begin designing project parts
Week 7	• Solidworks cont. • Shopbots • Waterjet • Vinyl cutter	Rapid prototyping	Design project to be manufactured using two RP methods
Week 8	• Basic closed loop control • Block diagrams • PID control	Control	Manufacture project prototypes

Week 9	• Impulse response • Frequency response • Bandwidth	Control	Create plan for control of project
Week 10	• Impedance • Transfer functions • Matching / reflected inertia	Control	Implement control using microcomputer
Week 11	• Sensors • Data acquisition	Sensing and Comms	Implement sensing
Week 12	• Analog communication • Digital communication • Software drivers	Sensing and Comms	Debugging and comms
Week 13	• Ethics in robotics • Societal impact • Project work week	Robo-ethics	Testing and preparation for demo
Week 14	• Wrap-up • Project presentations	Presentations	Final project presentations and demos

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-11-18
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Robotics Subject: ROB Catalog: 330
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Localization, Mapping, and Navigation
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) SLAM & Navigation
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) The development of full-stack autonomous navigation and semantic mapping for mobile robots. Topics include dead reckoning from odometry, sensor modeling of LIDAR and IMUs, simultaneous localization and mapping, semantic scene understanding, and an introduction to deep learning methods for convolutional feature learning and object detection.	
☑	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: Undergraduate Max: 4 Graduate Max:	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student	
☑	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits: 0	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:		
☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

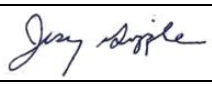
	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) (IOE 265 or EECS 301) and (ME 240 or ME 360) and (Math 215 or Math 216)
☑	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) ROB 204, EECS 280 Minimum grade requirement: C-
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☑ Lab ☐ Discussion ☐ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered ☑ Fall ☐ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Katie Skinner Cognizant Faculty Member Title: Assistant Professor

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Christina Hollis Email: crhollis@umich.edu Phone: 734-763-2869

CoE Curriculum Committee Representative:	Print:	Date:
CoE Curriculum Committee Chair:	Print:	Date:
Home Department Chair: 	Print: Jessy Grizzle	Date: 11-18-2021
Cross-Listed Department Chair:	Print:	Date:
Cross-Listed Department Chair:	Print:	Date:
Cross-Listed Department Chair:	Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description The development of full-stack autonomous navigation and semantic mapping for mobile robots. Topics include dead reckoning from odometry, sensor modeling of LIDAR and IMUs, simultaneous localization and mapping, semantic scene understanding, and an introduction to deep learning methods for convolutional feature learning and object detection.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation) 0
Contact hours (lab)	Contact hours (lab) 2

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
The objective of Robotics 330 is to introduce methods for the development of semantic autonomous navigation systems in current autonomous systems such as drones, self-driving cars, planetary rovers, and autonomous surface vehicles. Perception involves understanding sensors and signal processing to provide measurements for high-level inference and algorithmic implementations. The students will become familiar with sensing pipelines, the knowledge behind information processing for robot perception, and modern tools to these ends.

Robotics 330 focuses on the development of algorithms to solve robot perception and navigation problems using real sensory data provided by cameras, LIDAR, IMUs, and encoders. The students will program these models and algorithms using widely-used programming languages in robotics, namely, Python, C++, and MATLAB/Julia.

ROB 330 will provide a sufficient introduction to state-of-the-art deep learning methods using convolutional neural networks for feature learning, image classification, object detection and semantic segmentation in images. These topics will be integrated into a full stack perception and autonomous navigation package such that students will see the outcome in a visually appealing manner.

Students who take ROB 330 will learn aspects of the C++ and Python programming languages as primary language and MATLAB/Julia as the secondary languages for project and lab components. Python is the most common language for research and development among computer vision, machine learning and AI, and robotics communities due to the availability of open-source libraries and ease of use. C++ and MATLAB/Julia are used today in many fields of engineering. C++ is a pervasive standard for software development in widespread use and real-time robotics software development. Julia is an emerging language suited to the needs of modern engineers and scientists. Julia is comparable to MATLAB and Python in its powerful capabilities for numerical computation and enables computational thought that can be readily

translated to new languages. Students will apply their previous programming knowledge to robot perception problems while mastering scientific programming for solving real-world data and robotics problems.

Special resources of facilities required for this course:
Availability of a CAEN Lab and access to lab space for 2 hour weekly lab sessions.

Supporting statement:
Robotics 330 acts as a bridge between ROB 101, 102, 103, and 204 and 400-level courses in robotics. Students will gain a sufficient understanding of robotic sensing and perception systems and an introduction to learning-based methods for semantic scene understanding and navigation required in future steps of undergraduate and graduate degrees in robotics and artificial intelligence.

Students will be evaluated through individual take-home problem sets due every 2-3 weeks and a final take home project. There will be three in-lab group projects due every 4-6 weeks and will be cumulative throughout the semester, with each project building on the previous project. Group projects will be assessed through peer review. This will provide students with intermediate feedback for testing components of their full-stack autonomous navigation system. Grading will be broken down into roughly 60% for projects, 20% for problem sets, and 20% final take home project.

ROB 330 is filling a gap in the curriculum for the Robotics Undergraduate degree as none of the existing computer vision and machine learning courses are developed for embedded intelligent systems and semantic autonomous navigation in 3D environments. Students will integrate their knowledge of mathematics (ROB 101 and other math courses) with robot hardware (sensors) in ROB 103, and AI and programming, ROB 102, in a coherent robotic perception system that supports today’s autonomous system development.

Schedule (14 weeks total)

	Lecture Topics	Lab Activity	Objectives
Week 1	<u>Introduction</u> • Course overview • What is robot perception? • Why is it hard (not solved)? • Sensors for perception	• Robot basic knowledge • Setup steps • Safety instructions	**Introduction to robot perception.** Understanding the pipeline of data acquisition, signal processing, and inference using direct or indirect measurements.
Week 2	<u>Rigid Motion Geometry</u> • 2D and 3D rigid motion • Robot motion models • Cartesian coordinate frames • Robot position and orientation • Rotation matrices • Orthonormality and SO(3) group • Euler Angles • Rigid Motions and SE(3) group • Homogeneous 3D transforms • Composition of transforms	• Motor, encoder test • LCM	**Getting familiar with the 2D and 3D geometric space and rigid motion to model a robot motion.** Use sensors for dead reckoning.
Week 3	<u>Odometry</u> • Wheel Encoders • Inertial Measurement Units • Odometry • Differential drive kinematics • Actuators • PID control • Dead reckoning	• Setpoint challenge tutorial	
Week 4	<u>Probabilistic Methods</u> • Probability introduction • Graphical models • Bayesian inference	• Setpoint challenge practice	
Week 5	<u>Mapping</u> • Occupancy grids • Counting sensor model • Binary Bayesian Filtering	• Setpoint challenge materials due • Setpoint challenge trials	**Implement Robotic occupancy mapping.**

Week 6	<u>Localization</u> • Monte Carlo localization • Sequential Bayesian filtering • Nonparametric distributions • Particle filtering	• Escape challenge tutorial	**Implement robot localization using motion and 2D/3D sensors.** Understanding the meaning behind indirect and direct data processing.
Week 7	<u>Planning</u> • Frontier exploration • A-star algorithm	• Escape challenge practice	
Week 8	<u>RGB Sensing</u> • 2D sensing using cameras and projection model • Monocular vision • Scale ambiguity	• Escape challenge practice	
Week 9	<u>3D Sensing</u> • LIDAR point clouds • 3D sensing • Geometry, appearance, and semantic notions • Projective data association	• Escape challenge materials due • Escape challenge trials • Detection challenge tutorial	**Getting familiar with 2D and 3D sensing hardware and point cloud processing tools**. Derive models and perform sensor calibration.
Week 10	<u>Deep Learning</u> • Convolutional neural networks • Representation/Feature learning • Image classification	• Detection challenge practice	**Implement a CNN for feature learning and classification.** Revisit localization and use objects as landmarks.
Week 11	<u>Object Detection</u> • Semantic scene understanding • Object-level scene understanding and localization • Object detection	• Detection challenge practice	
Week 12	<u>Semantic Segmentation</u> • Deep learning for semantic segmentation • Semantic segmentation from imagery	• Detection challenge trials • Detection challenge materials due	

Week 13	<u>Semantic Mapping</u> • Semantic counting sensor model and Bayesian inference • Bayesian inference for semantic sensor model.	• Individual take home final project	
Week 14	• Wrap-up • State-of-the-art/future of robot perception	• Individual take home final project	

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-15
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Robotics Subject: ROB Catalog: 340
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Human-Robot Interaction
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Hum-Rob Int
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Covers psychophysics, modeling a human operator within a control loop, and measuring human performance in the context of robotic systems. These topics support robotic systems in unstructured and unknown environments with a human supporting decision making, mitigating risks and extending capabilities of the human-robot team.	
☑	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: Undergraduate Max: 4 Graduate Max:	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student	
☑	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits: 0	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent	Drop Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) ROB 311
☑	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) ROB 204 Minimum grade requirement: C-
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☑ Recitation ☐ Lab ☐ Discussion ☐ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered ☑ Fall ☐ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Leia Stirling	Cognizant Faculty Member Title: Associate Professor

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Chrisitna Hollis Email: crhollis@umich.edu Phone: 734-763-2869

CoE Curriculum Committee Representative:		Print:	Date:
CoE Curriculum Committee Chair:		Print:	Date:
Home Department Chair:	Jessy Grizzle	Print: Jessy Grizzle	Date: 10/14/2021
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Covers psychophysics, modeling a human operator within a control loop, and measuring human performance in the context of robotic systems. These topics support robotic systems in unstructured and unknown environments with a human supporting decision making, mitigating risks and extending capabilities of the human-robot team.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation) 1
Contact hours (lab)	Contact hours (lab) 0

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
This course will be part of the Robotics Undergraduate program pathway options. The course is intended to provide students with more depth on human-robot interaction, extending ideas introduced in ROB 204. There is a specific emphasis on mathematical models of human cognitive mechanisms in the context of interactive robotic systems.

This course is part of the emerging undergraduate major degree in Robotics. Assuming approval of the Robotics Undergraduate Program, this course will serve as an intermediate level course for students majoring in Robotics. We expect students will be ready to enroll in this course as early as the Winter 2023 semester. As a new offering in the planned Robotics Undergraduate Program, this has not been offered previously. The first offering of this course is expected to be a limited-enrollment pilot that will ramp up enrollment in future semesters. The Robotics Undergraduate Program does not plan for ABET accreditation for the immediate horizon. This course is not planned to be an essential part of an ABET accredited degree program, but has appropriate ABET objectives listed in case they are needed.

Special resources of facilities required for this course:
None

Supporting statement:
The proposed course supports design of robotic systems that have direct interactions with humans during real-time operations. The inclusion of the human operator in a closed-loop system provides capabilities for robots to be used in unstructured and unknown environments as the human can support decision making, mitigating risks and extending capabilities. This class provides context for how we can measure human perception, how the human operator can be modeled in the control loop, as well as ways to measure performance of the human in the context of robotic systems.

The course will be assessed using assignments, exams, and a final project. All assessments are individual. The breakdown is as follows:

Assignments - 65%
Final Project - 15%
Midterm Exam - 10%
Final Exam - 10%

Assignments include implementation of methods, small experiments, and paper-based modeling. For example, the assignment associated with the psychophysics module will include a small data collection and then fitting of psychometric curves to the collected data, assessing the pros and cons of the different methods and the operational interpretation of the outcomes. The human-in-the-loop control module will include computer simulation implementations of the models presented, evaluating implementations on relevant criteria. For the human motion assessment, assignments will include interpretation of data, as well as implementation of methods to take sensor measures to relevant outcome metrics.

Learning Objectives
Describe the distinction between sensation, perception, and behavior.
Design an experiment to assess the just noticeable difference for a sensory quality.
Distinguish haptic information and power exchange in force/motion signals and motor commands/haptic sensation.
Provide the pros and cons for keeping a human in the loop vs. automating a task or process.
Describe the role of biomechanics and neural control in a human-in-the-loop system.
Use quantitative and qualitative approaches to evaluate and analyze human-robot movement and interactions.
Describe the communication requirements associated with the spectrum of robots ranging from a robot as a tool to a robot as a teammate.

Schedule (15 weeks total)

Week	Topic
Week 1	History of cognitive models and the conception of self
Week 2	Psychophysics: Introduction to classical methods
Week 3	Psychophysics: Finding a Just Noticeable Difference
Week 4	Psychophysics: Signal detection theory
Week 5	Sensation and perception: Modality, mapping, and language
Week 6	Haptics: Information for cueing vs. coupling
Week 7	Feedback systems and loop closures: The role of hardware versus the human
Week 8	Human-in-the-loop Control: Motion, interaction, and impedance control
Week 9	Human-in-the-loop Control: Internal models and feedforward control
Week 10	Human-in-the-loop Control: Arbitrating decision making in the presence of modes
Week 11	Social robots: Communication for the spectrum of robots as tools to teammates
Week 12	How to measure motion: Defining metrics of performance
Week 13	How to measure motion: Kinematics
Week 14	How to measure motion: Forces and Interaction
Week 15	Final Project Presentations

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-19
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Aerospace Engineering Subject: AEROSP Catalog: 501
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Aerospace Economics
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Aero Economics
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Graduate course in informing optimal engineering decisions based upon product lifecycles and customer usage profiles. This course drills down into customer needs and how they're fulfilled by aerospace products, ultimate lifecycles of those products, how they inform the best product decisions, and future considerations around technology, sustainability, and industry trends.	
☑	Full Term Credit Hours Undergraduate Min: Graduate Min: 3 Undergraduate Max: Graduate Max: 3	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Non-Rackham Graduate Student, Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☑ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☑	Terms Typically Offered ☑ Fall ☑ Winter ☐ Spring ☐ Summer ☑ Spring/Summer

Cognizant Faculty Member Name: AEROSP 501 TBA	Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Linda Weiss Email: lweiss@umich.edu Phone:

CoE Curriculum Committee Representative: K. G. Powell Print: Kenneth G Powell Date: 11/17/21

CoE Curriculum Committee Chair: Print: Date:

Home Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Graduate course in informing optimal engineering decisions based upon product lifecycles and customer usage profiles. This course drills down into customer needs and how they're fulfilled by aerospace products, ultimate lifecycles of those products, how they inform the best product decisions, and future considerations around technology, sustainability, and industry trends.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
COURSE TOPICS:

1. Customer -- operations (both aircraft and spacecraft), infrastructure, purchasing process and key decision parameters.
2. Air - and spacecraft lifecycles -- design & development, manufacturing, usage, maintenance & sustainment, disposal.
3. Future trends and considerations -- advanced air mobility, electrification, democratization of space, sustainability -- and how these trends inform future designs.

COURSE OBJECTIVES
Prepare students to set leading product strategies based upon enterprise knowledge, informed by customer usage profiles, product lifecycle knowledge, and technology & industry trends.

COURSE OUTCOMES
Upon course completion, students should have the skills to:

- Articulate customer needs and how they are fulfilled through aerospace products (hardware, software)
- Translate customer requirements (subjective) into quantifiable design parameters and specifications

- Make effective product decisions based upon customer technical and business objectives, and product usage profiles
- Understand industry and technology trends, how they will impact their customers and set future product and technology strategy within their organizations

ASSESSMENT TOOLS

1. Weekly exercises based upon real-world technology and business examples
2. Formal case study spanning the length of the 7-week course and integrating all of the learning objectives
3. Quizzes
4. Final exam

APPENDIX III – AEROSPACE LEADERSHIP M.ENG. SYLLABI

AEROSP 501 – AEROSPACE ECONOMICS

Course Description and Objectives

A graduate level course in informing optimal engineering decisions based upon product lifecycles and customer usage profiles. This course will drill down into customer needs and how they are fulfilled by aerospace products, the ultimate lifecycles of those products and how they inform the best product decisions, and finally future considerations around technology, sustainability, and industry trends.

It will include case studies using real-world aerospace asset data, organized and developed so students do their own analyses and develop optimized systems designs.

Course teachings will be provided in lecture. Students will apply the teachings to their own specific projects, and will be graded on how well they apply the teachings to specific design & manufacturing optimization case studies.

Upon course completion, students should have the skills to:

- Articulate customer needs, and how they are fulfilled through aerospace products (hardware, software)
- Translate customer requirements (subjective) into quantifiable design parameters and specifications
- Make effective product decisions based upon customer technical and business objectives, and product usage profiles
- Understand industry and technology trends, how they will impact their customers, and set future product and technology strategy within their organizations

AEROSP 501 will be an online course included as part of the Master of Engineering (M.Eng.) in Aerospace Leadership degree program.

Assessment Tools and Grading

- Weekly exercises based upon real-world technology and business examples
- Formal case study spanning the length of the 15-week course, and integrating all of the learning objectives
- Quizzes
- Final exam

Weekly Syllabus

Week	Block	Lecture Topic
1		Course Introduction & Outline, Grading, Expectations
2	The Customer	Airline Operations and Aircraft Utilization
3		Other Aircraft Entity Operations (MRO, etc.)
4		Spacecraft Operations
5		Aerospace Infrastructure (airports, suppliers, spaceports, etc.)
6	The Lifecyle	Aircraft Design & Development
7		Aircraft Manufacturing
8		Fall/Spring Break
9		Spacecraft Design & Development
10		Spacecraft Manufacturing
11		Aircraft and Spacecraft Maintenance & Sustainment
12	The Future	Team Performance Assessment
13		PDR Dry Runs
14		Lecture cancelled – PDR Week
15		Finals

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-22
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Aerospace Engineering Subject: AEROSP Catalog: 502
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Aerospace Leadership Capstone
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Aero Lead Capstone
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Graduate Capstone course/ project where students work in teams of 4-5 to develop a comprehensive technology, product development, and business proposal, and apply all program learnings to the project. Students present to a panel of industry judges who grade the quality of the project, presentation, and use of the tools/methods.	
☑	Full Term Credit Hours Undergraduate Min: Graduate Min: 3 Undergraduate Max: Graduate Max: 3	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent	Drop Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☑ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☑	Terms Typically Offered ☑ Fall ☑ Winter ☐ Spring ☐ Summer ☑ Spring/Summer

Cognizant Faculty Member Name: George Halow	Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative:  Print: Kenneth G Powell Date: 11/17/21

CoE Curriculum Committee Chair: Print: Date:

Home Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Graduate Capstone course/ project where students work in teams of 4-5 to develop a comprehensive technology, product development, and business proposal, and apply all program learnings to the project. Students present to a panel of industry judges who grade the quality of the project, presentation, and use of the tools/methods.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
see attachment

AEROSP 502 – CAPSTONE

Course Description and Objectives

A graduate level Capstone course and project which are the culmination of all learnings in the M.Eng. in Aerospace Leadership Program. Students will work in teams of 4-5, develop a comprehensive technology, product development, and business proposal -- subject to instructor approval -- and apply all course learnings to the project. The project will be presented to a panel of industry judges, who will grade the quality of the project, presentation, and use of the tools and methods.

Course teachings will be provided in lecture. Students will apply the teachings to a Capstone project, evaluated on:

- How well they apply the class teachings
- How they have integrated the teachings of other courses in the program
- How compelling their business proposition is, and how convincingly they have presented it to a panel of outside industry judges (who will grade their presentations)

Upon course completion, students should have the skills to:

- Establishment of a strategic plan and business case
- Critical technology evaluation processes, and decision tools
- Understanding key stakeholders and decision-makers, and how to ensure you provide and convey well decision-critical information
- Synthesis of all MEng coursework completed to date
- Effective presentations

AEROSP 502 will be an online course included as part of the Master of Engineering (M.Eng.) in Aerospace Leadership degree program.

Assessment Tools and Grading

- Final Capstone project -- written proposal
- Final Capstone presentation to industry judges
- Interim reviews with instructor(s)
- Peer evaluations -- both within the team and amongst teams

Weekly Syllabus

Week	Block	Lecture Topic
1		Course Introduction & Outline, Grading, Expectations, Project Management Refresher
2		Structured Technology and Business Proposals – How to Write a Business Plan
3		Technology or Product Venture Value Proposition – Business Case and Sensitivity
4		Preliminary Business Proposals Report-Out – Selection/Confirmation of Teams and Topics
5		Risk Management and Risk Mitigation Strategies – and Backup Plans
6		Leadership Communication
7		Coached Preliminary Dry Runs – Capstone Presentations
8		Fall/Spring Break
9		Preliminary Dry Run Assignments Recap and Balance of Semester Plans
10		Stakeholder Mapping
11		Raising Capital and Resources – Entrepreneurship and Intrapreneurship
12		Boundary Conditions – Competitors, Substitutes, Technology Partners
13		Coached Final Dry Runs
14		Paper Finalization, Pre-Filing with Judges
	Final Project Report-Outs (Judged, Graded)	

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-25
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING			**REQUESTED LISTING**		
☑	Dept (Home): Subject: Catalog:			Dept (Home): Aerospace Engineering Subject: AEROSP Catalog: 505		
☐	☐ Course is Cross-Listed with Other Departments			☐ Course is Cross-Listed with Other Departments		
	Department	Subject	Catalog Number	Department	Subject	Catalog Number
☑	Course Title (full title)			Course Title (full title) Engineering Tools & Methods		
☑	Abbreviated Title (20 char)			Abbreviated Title (20 char) Engr Tools & Methods		
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) A Model-Based Systems Engineering (MBSE) course covering physical and virtual engineering, emphasizing move from physical to virtual. Correlations between physical and virtual evaluations for different technologies and systems will be discussed. Formal requirements delivery through MBSE, and Six Sigma (6σ) tools/processes will drive understanding of MBSE model use and limitations.					
☑	Full Term Credit Hours Undergraduate Min: Undergraduate Max:	Graduate Min: 2 Graduate Max: 2		Half Term Credit Hours Undergraduate Min: Undergraduate Max:	Graduate Min: Graduate Max:	
☑	Course Credit Type Rackham Graduate Student, Non-Rackham Graduate Student					
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:			☐ Course is Y graded ☐ Can be taken more than once in the same term		

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent	Drop Consent ☐ Department Consent ☑ Instructor Consent ☐ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☑ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered ☑ Fall ☑ Winter ☐ Spring ☐ Summer ☑ Spring/Summer

Cognizant Faculty Member Name: GeorgeHalow	Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative: K. G. Powell Print: Kenneth G Powell Date: 11/17/21

CoE Curriculum Committee Chair: Print: Date:

Home Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description A Model-Based Systems Engineering (MBSE) course covering physical and virtual engineering, emphasizing move from physical to virtual. Correlations between physical and virtual evaluations for different technologies and systems will be discussed. Formal requirements delivery through MBSE, and Six Sigma (6σ) tools/processes will drive understanding of MBSE model use and limitations.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 2
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
See attachment

AEROSP 505 – ENGINEERING TOOLS & METHODS

Course Objectives

A Model-Based Systems Engineering (MBSE) course which covers physical and virtual engineering, emphasizing the move from physical to virtual. Correlations between physical and virtual evaluations for different technologies and systems will be discussed. Formal requirements delivery through MBSE, and Six Sigma (6σ) tools and processes, will be incorporated to help drive complete understanding of MBSE model use, and limitations in specific instances.

Course teachings will be provided in lecture. Students will apply the teachings to their own specific projects, and will be graded on:

- How well they apply the teachings
- Their ability to discern robust and non-robust modeling, and how to use them strategically to efficiently to solve engineering problems

Upon course completion, students should have the skills to:

- Understand and apply the most efficient evaluation methodologies to solve critical engineering issues, recognizing benefits and limitations of various physical and virtual evaluation tools
- Apply statistical and 6σ tools and process, for high-confidence product decisions even under uncertainty
- Know when sufficient confidence in a decision is achieved, and action can be taken without further evaluation
- Implement MBSE tools and processes after a decision under uncertainty and course of action have been taken, to monitor effectiveness and take additional action if required
- Make strategic organizational decisions around people, facilities investment, and process implementation to maximize the effectiveness and efficiency of critical product actions

AEROSP 505 will be an online course included as part of the Master of Engineering (M.Eng.) in Aerospace Leadership degree program.

Assessment Tools and Grading

- Virtual labs
- Quizzes
- Mini-case analyses
- Final project comparing actual physical and virtual results, and explanation why either/both are required for confidence in the final decision. Report-out to industry panel

Weekly Syllabus

Week	Lecture Topic
1	Course Introduction & Outline, Grading, Expectations
2	Intro to Quality Engineering
3	Physical Testing Methodologies – Baseline
4	Design of Experiments
5	Statistical Modeling
6	Model/Testing Correlation
8	Project Selection Report-Out & Confirmation
10	6σ Root Cause Analysis (RCA)
11	Multi-Criteria Decision Making
12	Field Validation/Flight Testing Principles
16	Final Project Report-Outs

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☐ New Course
- ☑ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-10-18
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☐	Dept (Home): Biomedical Engineering Subject: BIOMEDE Catalog: 350	Dept (Home): Biomedical Engineering Subject: BIOMEDE Catalog: 350
☐	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number
☐	Course Title (full title) Introduction to Biomedical Design	Course Title (full title) Introduction to Biomedical Design
☐	Abbreviated Title (20 char) Intro to BME Design	Abbreviated Title (20 char) Intro to BME Design
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Problem-based learning to introduce students to biomedical engineering design concepts, tools, and methodologies. Students will work in small groups and use virtual design and computational tools to propose and validate feasible solutions to real-world biomedical engineering problems with industrial and/or clinical relevance.	
☐	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: Undergraduate Max: 4 Graduate Max:	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☐	Course Credit Type Undergraduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: Biomedical Engineering Catalog: 350

☐

Grading Basis
- ☑ Graded (A – E)
- ☐ Credit/No Credit
- ☐ Satisfactory/Unsatisfactory
- ☐ Pass/Fail
- ☐ Business Administration

Grading
- ☐ Not for Credit
- ☐ Not for Degree Credit
- ☐ Degree Credit Only

Add Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

Drop Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

	CURRENT LISTING	REQUESTED LISTING
☑	Advisory Prerequisite (254 char) BIOMEDE 221 and 231	Advisory Prerequisite (254 char) BIOMEDE 211 and Biomede 221
☑	Enforced Prerequisite (254 char) MATH 216 or 256 or 286 Minimum grade requirement: C-	Enforced Prerequisite (254 char) Engr 100, and [Math 216 or 256 or 286] and Biomede 231, and Biomede 241 Minimum grade requirement: C-
☐	Credit Exclusions	Credit Exclusions

☐

Course Components

	Graded Component
☑ Lecture	☑
☐ Seminar	☐
☐ Recitation	☐
☑ Lab	☐
☐ Discussion	☐
☐ Independent Study	☐

Terms Typically Offered
- ☑ Fall
- ☑ Winter
- ☐ Spring
- ☐ Summer
- ☐ Spring/Summer

Cognizant Faculty Member Name: Xueding Wang Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative:  Print: Cameron Louttit Date: 11/8/2021

CoE Curriculum Committee Chair: Print: Date:

Home Department Chair: Ariella Shikanov Print: Ariella Shikanov Date: 10/19/2021

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description This course uses problem-based learning to introduce students to biomedical engineering design concepts, tools, and methodologies. Students will work in small groups and use virtual design and computational tools to propose and validate feasible solutions to real-world biomedical engineering problems with industrial and/or clinical relevance.	Course Description Problem-based learning to introduce students to biomedical engineering design concepts, tools, and methodologies. Students will work in small groups and use virtual design and computational tools to propose and validate feasible solutions to real-world biomedical engineering problems with industrial and/or clinical relevance.
Class Length Full term	Class Length Full term
Contact hours (lecture): 3	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab) 1	Contact hours (lab) 1

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
BIOMEDE 350 is a required core course for all biomedical engineering undergraduate students.

Special resources of facilities required for this course:

Supporting statement:
Changing pre-requisites to make the registration process easier for students. Overrides will no longer be required.

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-11-04
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Civil & Environmental Engin Subject: CEE Catalog: 518
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Deployable and Reconfigurable Structures
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Depl/Reconfig Struc
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Covers theory, analysis, and design of deployable and reconfigurable structures, including linkage-based, origami, and inflatable systems. Students will learn about kinematics, geometric constraints, stability, stiffness, energy behaviors, design, material systems, fabrication, and actuation. Includes a student project to explore and design practical deployable structures.	
☑	Full Term Credit Hours Undergraduate Min: 3 Graduate Min: 3 Undergraduate Max: 3 Graduate Max: 3	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student, Rackham Graduate Student, Non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: Catalog:

☑

Grading Basis
- ☑ Graded (A – E)
- ☐ Credit/No Credit
- ☐ Satisfactory/Unsatisfactory
- ☐ Pass/Fail
- ☐ Business Administration

Grading
- ☐ Not for Credit
- ☐ Not for Degree Credit
- ☐ Degree Credit Only

Add Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

Drop Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) Course equivalent to CEE 412, CEE 510, or ME 305
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☑

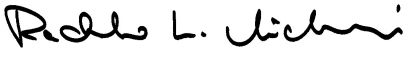
Course Components / Graded Component
- ☑ Lecture — ☑
- ☐ Seminar — ☐
- ☐ Recitation — ☐
- ☐ Lab — ☐
- ☐ Discussion — ☐
- ☐ Independent Study — ☐

Terms Typically Offered
- ☐ Fall
- ☑ Winter
- ☐ Spring
- ☐ Summer
- ☐ Spring/Summer

Cognizant Faculty Member Name: Evgueni Filipov Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative:  Print: Radoslaw L. Michalowski Date: 11/5/2021

CoE Curriculum Committee Chair: Print: Date:

Home Department Chair:  Print: Jerome Lynch Date: 11/14/21

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Covers theory, analysis, and design of deployable and reconfigurable structures, including linkage-based, origami, and inflatable systems. Students will learn about kinematics, geometric constraints, stability, stiffness, energy behaviors, design, material systems, fabrication, and actuation. Includes a student project to explore and design practical deployable structures.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture):
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
This course introduces students to existing and emerging types of deployable and reconfigurable structures including linkage-based, origami, and inflatable systems. Students learn the theory associated with these types of structures as well as non-traditional methods required for their design and analysis. The course also covers practical topics in how to fabricate and realize deployable structures in practice. This is one of the first such courses offered in the U.S. Contacts in industry have expressed interest in recruiting students with the unique skill set gained from this course.

Special resources of facilities required for this course:

Supporting statement:
This course introduces students to existing and emerging types of deployable and reconfigurable structures including linkage-based, origami, and inflatable systems. Students learn the theory associated with these types of structures as well as non-traditional methods required for their design and analysis. The course also covers practical topics in how to fabricate and realize deployable structures in practice. This is one of the first such courses offered in the U.S. Contacts in industry have expressed interest in recruiting students with the unique skill set gained from this course.
The course was offered once as CEE 501.067 in the Winter semester of 2020. The enrollment for this first time offering included 8 CEE students and 2 ME students. Student feedback and course evaluations were overwhelmingly positive. I

expect future offerings of the course will attract more interest with expected future enrollments to be between 20-30 students.

CEE 518 – Deployable and Reconfigurable Structures
Winter 2022 – Syllabus

Instructor: Evgueni T. Filipov - Office: 2144 GG Brown - Email: filipov@umich.edu

Lectures: Mon. Wed. 2:30pm – 4:00pm, 2147 GG Brown

Office hours: Mon. Wed. 4:00pm – 5:00pm, 2144 GG Brown

Course Description: The course covers theory, analysis, and design of deployable and reconfigurable structures, including linkage-based, origami, and inflatable systems. Students will learn about kinematics, geometric constraints, stability, stiffness, energy behaviors, design, material systems, fabrication, and actuation. The course includes a student project to explore and design practical deployable structures.

Learning Objectives: Through this course you will learn to:

- Describe applications, advantages, and disadvantages of Deployable and Reconfigurable (D&R) structures in engineering.
- Formulate structural analysis models for linkage-based and scissor mechanism type structures.
- Formulate methods to simulate the kinematic movement of D&R structures.
- Recognize and describe over-constrained, infinitesimal, and self-stressed mechanisms.
- Evaluate stiffness and stability of D&R structures
- Evaluate the developability, flat foldability and rigid foldability of origami patterns.
- Fold and describe the kinematics of different origami patterns.
- Apply bar and hinge models to simulate the structural behavior of origami.
- Describe material systems, actuation methods, fabrication methods, and design considerations for common D&R structures.

Prerequisites: Exposure to the following topics: matrices and vectors, linear algebra, and matrix structural analysis. CEE 412 Matrix Structural Analysis or CEE 510 Finite Element Methods, or a similar class is recommended, but not required. Basic knowledge of MATLAB is expected.

Target audience: Advanced undergraduate and graduate students are encouraged to enroll in the class. Students from Civil Engineering, Mechanical Engineering, Architecture, Aerospace Engineering, and other disciplines are all welcome.

Lectures: A lecture schedule is available on canvas and lists the topics for the semester. The schedule will be revised and updated as necessary. Regular attendance is expected. If you have to miss class please contact the instructor to arrange for alternatives on participation activities and obtaining lecture notes.

Readings: A set of research papers related to deployable and reconfigurable structures will be provided by the instructor. Students are required to read those papers, and prepare a short one paragraph summary and five bullet points of their main impressions. The written summary should be prepared before the class on the following Wednesday. You will discuss the articles with your classmates during class, and hand in your summary after the discussion. In later reading assignments, students will select research papers of their own interest and prepare brief summaries on those papers to present to the classmates.

Participation: Class participation is strongly encouraged and expected. There will be in class reading discussions where everyone is expected to be engaged verbally (see above). Occasionally, supplementary in-class written and hands-on (e.g. fabrication) activities will be conducted.

Homework: Generally, homework problems are assigned on Mondays and are due two weeks later on Friday by 5pm (see schedule). Submit homework via Gradescope (see below). You must submit all homework assignments to complete the course. You are encouraged to discuss homework with your classmates, but everything you submit should constitute your own work and reflect your own understanding. Homework will often involve MATLAB programming.

Team project: During the second half of the course student teams (~3 students per team – assigned by the instructor) will perform a research project related to deployable and reconfigurable structures. The team may either propose their own research topic or can choose from a range of potential projects provided by the instructor. Teams will first prepare a project proposal for discussion and approval by the instructor. Students are expected to identify a research and/or design problem in the field, perform an in depth analysis, explore the system behavior, and draw conclusions from the findings. At the end of the semester, each team will submit a group report in a scientific format. The teams will also make a 3 minute lighting talk, and present their project to the class and guests from the College of Engineering community. Contributions of each individual in the team have to be specified in both the report and the presentation. More information on the project expectations and grading will be provided throughout the semester.

Midterm Exam: There will be one midterm exam that covers the course (Date TBD), and there will be no final exam. A list of topics will be provided to help you study and review.

Gradescope: We will be using Gradescope to manage homework, and exam grading this term. Gradescope allows us to provide fast and accurate feedback on your work, and allows you to keep a digital easily accessible version of all your work. Homework can be scanned using a smartphone, a regular scanner, or can be written using an I-Pad. PDF files (e.g. of your source codes and plots can be directly submitted). Homework and exam grades will be returned through Gradescope only. As soon as grades are posted, you will be notified so that you can log in and see your feedback. You may also submit regrade requests if you feel we have made a mistake. Your Gradescope login is your university email and you can set up an account (if you do not have one yet).

Grading: Homework 25%; Midterm 25%; Readings 5%; Project Proposal 5%; Project Presentation 10%. Project Report 30%;

Grading Criteria: To achieve a passing grade in the class you are expected to complete all homework, reading and project requirements. It is expected that you would complete all work by the scheduled deadlines, unless you make prior arrangements with the instructor. For an: Excellent A or A- grade – you must demonstrate mastery in the course concepts (in exams and homework), and assemble a thorough final project that addresses all aspects for your chosen system. For a: Good B+ to B- grade – you must demonstrate a good technical grasp of most course concepts (in exams and homework), and/or assemble a final project that addresses most aspects for your chosen system, but has small deficiencies in thoroughness or technical quality. For an Adequate C+ to C grade – you must demonstrate a general understanding of the course concepts with deficiencies in several topical areas, and/or assemble a final project with multiple areas that lack thoroughness.

Canvas: The canvas site will be used to post homework assignments, grades, and other materials.

Getting help: I encourage you to take advantage of my office hours. However, I am also happy to talk to you by appointment, or any time my office door is open, and I am not otherwise engaged.

Students Requiring Accommodations: Students who have documented disabilities and require accommodations should make an appointment to discuss their needs with the course instructor. Students with disabilities must contact the Services for Students with Disabilities (SSD) Office before classroom accommodations can be provided. Go to https://ssd.umich.edu/ for more information.

Ethics: You are expected to adhere to the UM Engineering honor code and rules of conduct in all your activities pertaining to this class. I will expect that you have read and understand the honor code: http://www.engin.umich.edu/college/academics/bulletin/rules .

Inclusion Statement: It is my intention that students from all backgrounds and perspectives will be well served by this course, and that the diversity that students bring to this class will be viewed as an asset.

I welcome individuals of all ages, backgrounds, beliefs, ethnicities, genders, gender identities, gender expressions, national origins, religious affiliations, sexual orientations, socioeconomic background, family education level, ability – and other visible and nonvisible differences. All members of this class are expected to contribute to a respectful, welcoming and inclusive environment for every other member of the class. Your suggestions are encouraged and appreciated.

Lived Name: I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records.

Student Well-Being: Students may experience stressors that can impact both their academic experience and their personal well-being. These may include academic pressure and challenges associated with relationships, mental health, alcohol or other drugs, identities, finances, etc.

If you are experiencing concerns, seeking help is a courageous thing to do for yourself and those who care about you. If the source of your stressors is academic, please contact me so that we can find solutions together. For personal concerns, U-M offers many resources, some of which are listed at Resources for Student Well-being on the Well-being for U-M Students website. You can also search for additional resources on that website.

Student Mental Health: As a student you may experience a range of issues that can cause barriers to learning, such as strained relationships, increased anxiety, alcohol/drug problems, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may lead to diminished academic performance or reduce a student's ability to participate in daily activities. The University of Michigan is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of support, services are available. You can learn more about the broad range of confidential mental health services available on campus via https://caps.umich.edu/mitalk.

University of Michigan
Winter 2020 Instructor Report With Comments
CEE 501-067: Special Topics CEE
Evgueni Filipov

8 out of 10 students responded to this evaluation.

Responses to University-wide questions about the course:

	SA	A	N	D	SD	N/A	Your Median	Univ-wide Median	School/College Median
This course advanced my understanding of the subject matter. (Q1631)	7	1	0	0	0	0	4.9	4.5	4.7
My interest in the subject has increased because of this course. (Q1632)	7	1	0	0	0	0	4.9	4.2	4.5
I knew what was expected of me in this course.(Q1633)	5	3	0	0	0	0	4.7	4.5	4.5
Overall, this was an excellent course.(Q1)	6	2	0	0	0	0	4.8	4.3	4.5
I had a strong desire to take this course.(Q4)	6	0	2	0	0	0	4.8	4.1	4.6
As compared with other courses of equal credit, the workload for this course was (SA=Much Lighter, A=Lighter, N=Typical, D=Heavier, SD=Much Heavier). (Q891)	0	0	7	1	0	0	2.9	3.0	3.0
How did the unexpected change to remote course format affect your learning experience in this course this term? (SA=Very Positively Affected, A=Somewhat Positively Affected, N=No Effect, D=Somewhat Negatively Affected, SD=Very Negatively Affected) (Q1840)*	1	1	2	4	0	0	2.5	2.4	2.4

Responses to University-wide questions about the instructor:

	SA	A	N	D	SD	N/A	Your Median	Univ-wide Median	School/College Median
Overall, Evgueni Filipov was an excellent teacher.(Q2)	5	3	0	0	0	0	4.7	4.6	4.7
Evgueni Filipov seemed well prepared for class meetings.(Q230)	6	2	0	0	0	0	4.8	4.8	4.8
Evgueni Filipov explained material clearly.(Q199)	6	2	0	0	0	0	4.8	4.7	4.7
Evgueni Filipov treated students with respect.(Q217)	6	2	0	0	0	0	4.8	4.8	4.9

Responses to questions about the course:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median
I increased my ability to apply math and science knowledge to engineering problems. (Q15)	5	3	0	0	0	0	4.7	4.4
I increased my ability to analyze and interpret data. (Q17)	5	2	1	0	0	0	4.7	4.3
My confidence in my design abilities increased because of this course. (Q20)	6	1	1	0	0	0	4.8	4.2
I gained valuable experience working in teams in this course. (Q21)	6	2	0	0	0	0	4.8	4.2
I increased my ability to formulate, and solve engineering problems. (Q23)	7	1	0	0	0	0	4.9	4.3
I developed a greater understanding of my responsibilities as a professional. (Q25)	5	2	0	0	0	1	4.8	4.3
This course improved my ability to communicate technical information, designs, and analyses. (Q28)	6	2	0	0	0	0	4.8	4.4
I developed a greater understanding of the impact of engineering on the environment. (Q30)	5	1	0	0	0	1	4.9	4.5
This course increased my desire to learn more about this subject in the future. (Q32)	6	1	1	0	0	0	4.8	4.3
I have a greater understanding of how course concepts apply to contemporary problems. (Q34)	6	2	0	0	0	0	4.8	4.3
I increased my ability to apply engineering tools and methods. (Q35)	5	3	0	0	0	0	4.7	4.4
I gained a good understanding of concepts/principles in this field. (Q121)	5	2	1	0	0	0	4.7	4.4
I developed the ability to solve real problems in this field. (Q125)	5	2	1	0	0	0	4.7	4.4
Work requirements and grading system were clear from the beginning. (Q232)	4	4	0	0	0	0	4.5	4.6
The amount of work required was appropriate for the credit received. (Q239)	5	3	0	0	0	0	4.7	4.3
Examinations covered the important aspects of the course. (Q356)	6	2	0	0	0	0	4.8	4.5
Exams were reasonable in length and difficulty. (Q360)	5	2	1	0	0	0	4.7	4.2
The grading system was clearly explained. (Q366)	6	2	0	0	0	0	4.8	4.7

Responses to questions about the instructor:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median
Evgueni Filipov gave clear explanations. (Q201)	5	3	0	0	0	0	4.7	4.6
Evgueni Filipov stressed important points in lectures/discussions. (Q203)	4	4	0	0	0	0	4.5	4.6
Evgueni Filipov appeared to have a thorough knowledge of the subject. (Q207)	7	1	0	0	0	0	4.9	4.8
Evgueni Filipov acknowledged all questions insofar as possible. (Q216)	7	1	0	0	0	0	4.9	4.8
Evgueni Filipov used class time well. (Q229)	6	1	1	0	0	0	4.8	4.7

The medians are calculated from Winter 2020 data. University-wide medians are based on all UM classes in which an item was used. The school/college medians in this report are based on classes that are graduate level with enrollment of 1 to 15 in College of Engineering.

Written Comments

What teaching methods worked well? [e.g. videoconferencing; asynchronous interaction; etc.] (Q1841)*

Comments
Pre recorded lectures with live "office hours" during class time
I liked that we still had live class so it felt personal. I also think we did a great job adapting the projects. I still learned a lot from my project and enjoyed getting to thing through the idea. But I enjoyed how flexible it became once this remote situation happened.
Videoconferencing with breakout rooms worked well.
In person meetings worked best as it allowed us to have proper discussions and engage in more collaborative work, especially when it came to projects.
For twice we watched the lecture recording beforehand, and then Q&A during class. This is very informative and high efficiency. The separate discussion room in Zoom also worked well for group work.
Live Videoconferencing, breakout sessions
Video conferencing as well as having a recorded copy of the video conferencing helped.

What were your greatest challenges in remote learning for this course? [e.g. internet connectivity; personal motivation; managing life stresses; etc.] (Q1842)*

Comments
Working on the project remotely
I struggled the most with homework 3. I was struggling to get the codes without resources but Professor Filipov was flexible with the due date and helped me understand.
Internet connectivity, lack of access to CAEN computers (mine is pretty old and has trouble with Matlab), we were unable to make a prototype for our project.
Internet connectivity, working on projects remotely
I always make some white noise from my end probably because of my microphone.
Internet connection, working in groups remotely
Nothing.

Comment on the quality of instruction in this course. (Q900)

Comments
This is my second time having Professor Filipov. I enjoyed my first class with him and learned a great deal in that class through a constant challenge. I also really enjoy and learned a lot in this class. You could tell how interested and knowledgeable he is on the material. I think he took our feedback well during this first time class and adjusted learning. All in all, I did learn a lot from this class and really enjoyed the project and research paper based learning. It was different than most other classes I took this year. I certainly hope it will be offered again!
The topic in this course is very interesting. Prof. Filipov largely broaden my knowledge in this field. The reading materials and the assignment are carefully selected. It was my first time to have reading assignment, and it is especially useful for students who want to proceed on to PhD project. The homework problems are also carefully selected, so that we know the structure of the lectures. We are also trained well on coding with MATLAB. The explanation of the coding package MERLIN is very helpful.
Great introductory class to origami structures.

* Due to the unexpected shift to remote instruction, questions 1840, 1841, and 1842 were added to all end-of-term Winter 2020 teaching evaluations.

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-11-09
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Elec Engin & Computer Sci Subject: EECS Catalog: 449
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☐		
☑	Course Title (full title)	Course Title (full title) Conversational Artificial Intelligence
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Conversational AI
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) The science and art of creating conversational AI spans multiple areas in computer science. Students will learn about and leverage advances in these areas to create conversational virtual assistants spanning natural language processing, dialogue management, response generation, and other applications.	
☑	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: Undergraduate Max: 4 Graduate Max:	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) EECS 485 or EECS 493
☑	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) EECS 281; (C or better, No OP/F) Minimum grade requirement: C
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☐ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered ☑ Fall ☑ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Jason Mars	Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative:		Print: Amir Kamil	Date: 11/12/21
CoE Curriculum Committee Chair:		Print:	Date:
Home Department Chair:		Print: Amir Kamil	Date: 11/12/21
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description The science and art of creating conversational AI spans multiple areas in computer science. Students will learn about and leverage advances in these areas to create conversational virtual assistants spanning natural language processing, dialogue management, response generation, and other applications.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 4
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
The end-to-end process of creating a technological contribution to the world is an important experience for CS students, and this course provides that experience in an engaging and thought-provoking way. Students start by identifying a meaningful societal challenge and devising how conversational technology can be applied to address that problem. They then design and build a complete system to solve the problem, gaining a range of experience from user interfaces and software infrastructure to artificial-intelligence models that enable the solution, culminating in a fully realized prototype. This team-based design and implementation process exemplifies what practitioners experience in the field. The course has been taught several times and has been well-received, demonstrating that student interest in the subject matter is quite strong. At the same time, courses in this area are few and far between across universities, and this offering is a significant pedagogical contribution to the field.

This course is intended to fulfill the MDE/Capstone requirement for CS-LSA and CS-Eng majors.

Past offerings:
Winter 2019: 46 students
Fall 2019: 43 students
Winter 2020: 69 students

Fall 2020: 31 students
Fall 2021: 61 students

Conversational Artificial Intelligence

Principles and Practice of Virtual Assistant AI

EECS 498, FALL 2020

(prereqs: 280, 281)

Summary

The science and art of creating conversational AI spans multiple areas in computer science. Learning about and leveraging advances in these areas to create state-of-the art conversational virtual assistants is the central focus of this course. Throughout the course, students will put into practice the end-to-end creation of a virtual assistant spanning natural language processing, dialogue management, response generation, and other applications. Students will also use tools that span both traditional techniques as well as cutting edge techniques for these AI with the goal of creating new experiences that go beyond existing virtual assistants. Students will be tasked with integrating the AI experiences they create with a set real APIs of their choosing (e.g., Spotify, Fitbit, Unity, etc.). The project culminates in a demo day where creations are shared for others to try, for this semester, these public demos will take the form of video submissions that will be posted on the course website.

In the creation of these virtual assistants, students will form groups of around 5-7 students to select a use case, design the virtual assistant, train AI capabilities, implement logic, and execute the end to end build out and integration into an existing public API. In class, students will learn about the broad landscape of NLP and Conversational AI from it's fundamental principles. Students will also learn state of the art techniques for various aspects of modeling language in deep learning, leveraging transfer learning to solve NLP problem, and gain very important experience understanding and interpreting research papers as the state of the art evolves. As an MDE, the grading of the course is predominantly project-based and students will be presenting the evolution of their project in course. Also students will gain valuable experience presenting technical ideas and evaluation through 2 paper presentations per group.

Instructor: Jason Mars (profmars@umich.edu)
(http://www.jasonmars.org)

IA: Eric Chen (ericch@umich.edu)

Lecture: MW 1:30-3, ONLINE

Credits: 4

Prerequisites: EECS 280, EECS 281 (optional: EECS 485)

Office Hours: M/F 3:30-4:30 (tentative), and On Demand

Course Website: TBD

Schedule by Week *(subject to slight changes)

8/31, 9/2	Course Introduction, Natural Language Processing - Syllabus and Logistics - Introduction to NLP and Course Scope
9/7, 9/9 *(no class 9/7, Labor Day)	NLP and AI Overview - Survey of NLP Landscape and Problems - Traditional vs ML based NLP - Group formation due: 9/11
9/14, 9/16	Deep Learning – NLP style - Deep learning applied to NLP - Understanding Papers and Metrics
9/21, 9/23	Project Pitches and Feedback - One page write-up and slides due 9/25
9/28, 9/30	Papers – Representing Language / Embeddings - Word2Vec, GloVe
10/5, 10/7	Papers – Representing Language / Embeddings - Bert, Elmo, Elactra
10/12, 10/14	Papers – Landscape of Embeddings - GPT-2 / GPT-3
10/19, 10/21	Group Deep Dives - Mon: Group 1, 2

	- Wed: Group 3, 4, 6
10/26, 10/28	Project Updates, Show and Tell - One page write-up and slides due 10/30
11/2, 11/4	Recap and Paper - Recap (Lecture), FastText
11/9, 11/11	Papers – Dialogue Management - Learning Goal Diag, Trans. State Gen
11/16, 11/18	Paper and Guest Lectures - OpenDialKG - Wednesday: Guest Lectures Brian Yang and Yiping Kang
11/23, 11/25 Thanksgiving Break!	TURKEY!!
11/30, 12/2	Final Project Presentations
12/7	Last Day Wrap-Up - Closing Lecture - Project submissions due

Grading

This is a very 'do heavy' course. A significant portion of the grade is allocated to the project and demos. Lets build some amazing stuff!

Project write-ups: 10%

- Pitch (one page): 5%
- Update (one page): 5%

Presentations: 30%

- Pitch: 10%
- Update: 10%
- Papers: 5% x 2

- (Final presentation counted below toward final project)

Paper Summaries: 10%

Final Project, Code, and Report: 50%

- Demo: 15%
- Code: 15%
- Final Deck + Writeup: 10%
- Final Presentation: 10%

Participation (extra credit): Up to 10% Extra Credit

Logistics and Details

Late Policy

Assignments are expected to be completed on time. However, for unavoidable situations where this is not possible, you may use up to 1 late day (24 hours) per assignment for a penalty of 10%. An additional 10% will be lost for each additional day. If students need special accommodations due to Covid, I'd be happy to make them but would like to be made aware before deadlines.

Assignment Submission

Projects should all be submitted in as a .zip file containing project code, and a PDF containing README content (setup / usage instructions).

MDE Project

This course will have a large team-based project that will require designing and building a virtual assistant. After group formation, an initial 'pitch' document and in-class presentation will help teams get feedback on their ideas. After that, there will be a few milestones on the way to a final project document, presentation, and demos. The objective of this project is to build a system from the ground up that work really well in practice. Be creative!

Honor Code

All students (including LS&A and Engineering) are required to observe the Engineering Honor Code in all assignments and exams. A copy of the honor code can be found at

http://ossa.engin.umich.edu/honor-council/. Please make sure that you clearly understand what constitutes cheating. If you are not sure in any specific case, you should ask the teaching staff. The University takes honor code violations seriously, and penalties can be severe. You are not allowed to share your code with anyone other than your partners. You are not allowed to make use of project or homework solutions by others, including solutions from previous semesters. Make sure that you do not upload your code on github public repositories, as this also constitutes violation of the honor code.

A1 — Project Pitch Presentation and Writeup

A1 is due Friday, 9/25.

An important aspect of project formulation is pitching your idea to a stakeholder. No matter how good an idea you might have, you must be able to convince a stakeholder of the value to be added if your idea is taken to fruition.

You will work with your group of up to 6 members to create a slide deck that consists of a presentation of 20-25 minutes.

You will also work with your group for on the ~1 page writeup answering 6 key questions.

Specification

Your goal is to formulate an exciting project idea to work on this semester. With your group, come up with a creative application that can leverage Conversational AI to solve a problem.

The project pitch is a description of a problem, current shortcomings in existing solutions, a proposed solution, and an assessment of value added once the project is completed. You will create a slide deck that describes all of these, and you will deliver a 20-25 minute presentation in class.

Yor presentation should cover:

- Problem
- User story for your usecase (give us a detailed narrative of someone solving their problem with your experience)
- Product feature set
- Reach goals, beyond the feature set
- Tools you plan to use
- Diagram of how you envision the system architecture of your experience
- APIs you plan to use and what they look like
- Key milestones you plan to meet
- How you will organize yourselves (roles, etc)
- Conclusion
- Anything else you want to share with us (under 25 mins :-P)

For the ~1 page writeup, answer these questions:

- What is the goal of this project?
- Why it is interesting/challenging?
- Is there any prior work/existing commercially available product that is similar to what you want to do?
- What's the difference?
- What are the features/functions?
- How to evaluate the results?

Resources

There are some examples of slides in the prior lecture deck posted online, however feel free to introduce or include anything else you might want to share about your project. Feel free to explain your project however you think is best.

Commentary

Based on your project pitch, you will receive feedback from the instructors and IAs. It is preferred that each member of the team does a portion of the presentation, though with some folks in various timezones a video would be just fine.

Feel free to delegate various aspects of the project to different members of the team as a way to divide up the presentation.

Hints

A lot of Conversational AI deployments rely on human-in-the-room thinking. What things would you talk about with a human helping you? What steps are discussed while solving a problem or accomplishing a task? For example, what things would you ask a teller if you wanted to withdraw money from a bank account? By thinking of a human-in-the-room, you can gain insights about the appropriate scope for a project idea.

Previous groups have used Google Slides to produce slide decks. You are welcome to do so, so long as you turn in a PDF version of the slides. Use whichever tools you like best but be sure to convert to PDF before submission.

You are given a great deal of leeway in constructing your presentation. Don't feel constrained. Be creative!

What To Turn In For A1

Please turn in two files:

TeamNameorNumberSlides.pdf, containing your group's pitch slides.

TeamNameorNumberWriteup.pdf (or .doc), a file containing the writeup

Grading Rubric

Quality Presentation and Slides (Clear, well organized, relevant figures)

1-10 points (by .1 points, e.g., 9.2/10)

Quality Writeup (Complete, clearly written)

1-5 points (by .1 points, e.g., 4.8/5)

Each member of each team needs to submit this assignment for easier management on Canvas.

A6 — Project Final Presentation and Writeup

A6 is due Friday, 12/4.

In this assignment, you will work with your team to deliver the final summary presentation of your project.

You will also deliver a live demonstration of your project.

Finally, you will deliver a video intro and demo that summarizes (and show's off) your project (5mins max).

Specification

The Final Presentation will be conducted virtually with the class. Your task is to present the culmination of your project to an audience that is unfamiliar with Conversational AI.

You will deliver a presentation with your group that assumes the audience knows nothing about your project. Your job is to convince such an audience that your project solves a problem, and explain how your Conversational AI project works at a high level. Think more of a product pitch to the broader world.

Your final presentation should tell us a problem, its scope, and then introduce your solution. The presentation should tell us why a virtual assistant can help solve your problem. You can describe the final architecture of your solution, how it was trained it, etc.

In addition, you will give a live demo of your project **The presentation and demo itself *should not exceed 25 minutes*.** In addition to this in-class presentation. Groups are to submit a link to the 5min video intro and demo for the virtual demo day page.

As with the other presentations this semester, I'll leave it to each group to decide who presents what.

There will also be questions at the end of your presentation.

Finally, you will turn in your final Deck + One-pager. You can certainly include extra material where appropriate, such as screenshots or findings from testing.

Given the diversity of projects, I'll leave it to each group to organize your presentation how you'd like.

For the ~1 page writeup, Please provide these details:

- Problem your VA solves
- Description of each feature (Screenshots would be nice ;-))
- How does the team feel about the outcome of their project.

Resources

There is no suggested slide deck for your final presentation. We want you to decide for your group what elements you think are important for clearly communicating a relevant problem, your understanding of conversational AI, how a virtual assistant solves a problem, and a compelling demonstration that your project can solve that problem.

You could discuss a Problem Statement, cite relevant news articles, show screenshots or photos of how the problem manifests, etc. to motivate your project. You could also discuss state graphs, intent classification, etc.

Commentary

This part of the project is meant to show off the highlights of your project that you've worked on this semester. Consider: if you're trying to pitch a project involving your virtual assistant, you should be comfortable demonstrating your expertise with your (Virtual Assistant) VAs topic area and the utility of the VA. We're looking for that understanding in addition to evaluating the quality of the project overall.

Hints

I will be taking on the role of someone who knows nothing of your prodcut during your presentation. I am trying to simulate a stakeholder that is distant from the technology but that is interested in the space. I am looking for your group to convince me that you understand the journey of building a VA to solve your problem, AND that your group's project solves a tangible, relevant problem.

You are given a great deal of leeway in constructing your presentation. Don't feel constrained. Be creative!

What To Turn In For A1

Please turn in the following:

* Link to your 5min demo video

* Link or Zip of relevant code (doesn't need to run, but show key implementations)

* TeamNameorNumberSlides.pdf, containing your group's project slides.

* TeamNameorNumberWriteup.pdf (or .doc), a file containing the writeup

Grading Rubric

Quality Presentation and Slides (Clear, well organized, relevant figures)

1-15 points (by .1 points, e.g., 9.2/10)

Quality Writeup (Complete, clearly written)

1-5 points (by .1 points, e.g., 4.8/5)

In Class Demo

1-15 points

Code/Demo Day Video

1-15 points

Each member of each team needs to submit this assignment for easier management on Canvas.

EECS 498

Conversational Artificial Intelligence

Principles and Practice of Virtual Assistant AI

Prof. Jason Mars

Phase 3 Begins!

- **Project write ups: 10%**
  - Pitch one-page: 5% **[DONE]**
  - Update one-page: 5% **[DONE]**
- **Presentations: 30%**
  - Pitch: 10% **[DONE]**
  - Update: 10% **[DONE]**
  - Paper presentation: 5% x 2 **[Going]**
  - **Paper summary paragraphs: 10%** (points for completion) **[Going]**
- **Final Project and Report: 50%**
  - Demo: 15% **[UP]**
  - Code: 15% **[UP]**
  - Final Deck + Writeup: 10% **[UP]**
  - Final Presentation: 10% **[UP]**
- **Participation (extra credit): 10%** [Going]

Instructor: Jason Mars (profmars@umich.edu) (http://www.jasonmars.org)

IA: Eric Chen (ericch@umich.edu)

Lecture: MW 1:30-3, ONLINE

Credits: 4

Prerequisites: EECS 280, EECS 281 (optional: EECS 485)

Office Hours: M/F 3:30-4:30 (tentative), and On Demand

Course Website: TBD

Schedule by Week *(subject to slight changes)

8/31, 9/2	Course Introduction, Natural Language Processing - Syllabus and Logistics - Introduction to NLP and Course Scope
9/7, 9/9 *(no class 9/7, Labor Day)	NLP and AI Overview - Survey of NLP Landscape and Problems - Traditional vs ML based NLP - Group formation due: 9/11
9/14, 9/16	Deep Learning – NLP style - Deep learning applied to NLP - Understanding Papers and Metrics
9/21, 9/23	Project Pitches and Feedback - One page write-up and slides due 9/25
9/28, 9/30	Papers – Representing Language / Embeddings - Word2Vec, GloVe
10/5, 10/7	Papers – Representing Language / Embeddings - Bert, Elmo, Electra
10/12, 10/14	Papers – Landscape of Embeddings - GPT-2 / GPT-3
10/19, 10/21	Group Deep Dives - Mon: Group 1, 2

2

	- Wed: Group 3, 4, 5
10/26, 10/28	Project Updates, Show and Tell - One page write-up and slides due 10/30
11/2, 11/4	Recap and Paper - Recap (Lecture), FastText
11/9, 11/11	Papers – Dialogue Management - Learning Goal Diag, Trans. State Gen
11/16, 11/18	Paper and Guest Lectures - OpenDialKG - Wednesday: Guest Lectures Brian Yang and Yiping Kang
11/23, 11/25 Thanksgiving Break!	TURKEY!!
11/30, 12/2	Final Project Presentations
12/7	Last Day Wrap-Up - Closing Lecture - Project submissions due

Grading

This is a very 'do heavy' course. A significant portion of the grade is allocated to the project and demos. Lets build some amazing stuff!

Project write-ups: 10%

- Pitch (one page): 5%
- Update (one page): 5%

Presentations: 30%

- Pitch: 10%
- Update: 10%
- Papers: 5% x 2

3

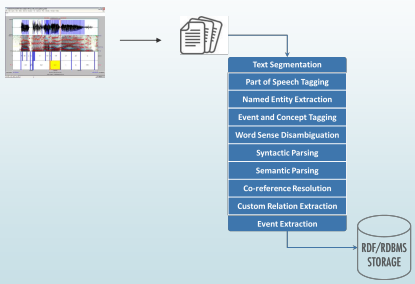
Final Papers!

Date	Paper	Group
11/4	Paper8-FastText.pdf	The Challengers
11/9	Paper9-LearnGoalDiag.pdf	Zoom U Bot
11/11	Paper10-DM-TransStateGen.pdf	Gossip Siri
11/16	Paper11-OpenDialKG	Happy Hooves 2.0

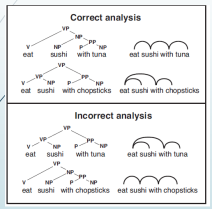
We started with NLP

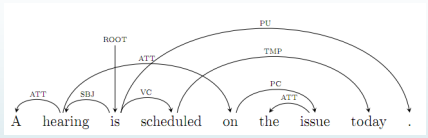
What is NLP? Then and Now

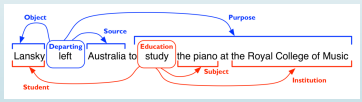
Refresher: Example Classic NLP Pipeline



Classic NLP: Inspired by Computational Linguistics

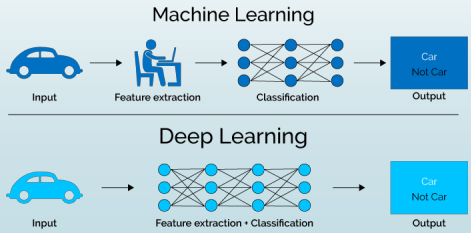


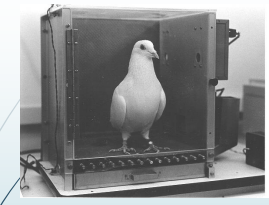


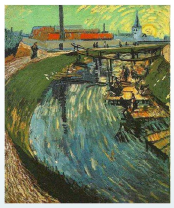


Enter Deep Learning

A machine learning subfield of learning **representations** of data.
Exceptional effective at **learning patterns**.
Deep learning algorithms attempt to learn (multiple levels of) representation by using a **hierarchy of multiple layers**
If you provide the system **tons of information**, it begins to understand it and respond in useful ways.

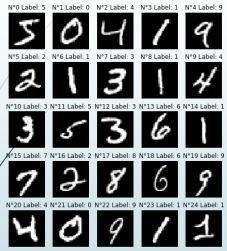


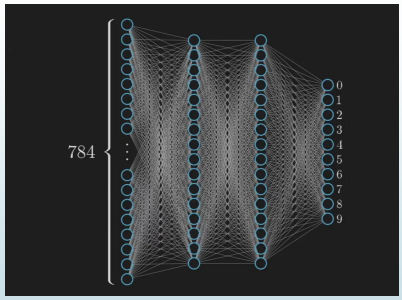




Pigeons were able to discriminate between Van Gogh and Chagall with 95% accuracy (when presented with pictures they had been trained on)

Big Picture on how DNNs Work

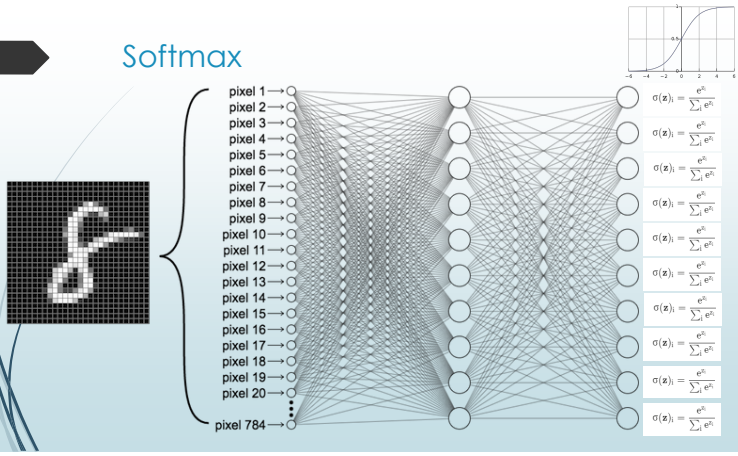




On infrence:

- 784 Pixels in
- Activations cascade through network
- Output distribution of values, take max as prediction

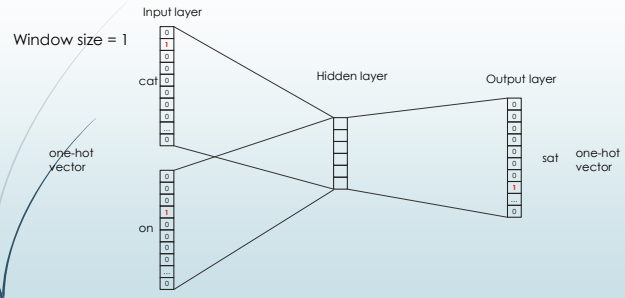
Softmax



"One-Hot Encoding"

- Naïve embedding
- Word = $w \in \mathbb{R}^n, n = dom(V)$

- Example
  - V = ["dog", "bites", "man"]
  - "dog bites man" = [[1,0,0],[0,1,0],[0,0,1]]
  - "man bites dog" = [[0,0,1],[0,1,0],[1,0,0]]



On to Language Models (Embeddings)

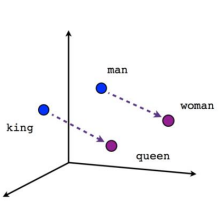
Changing the game with a burst of innovation

Word Representations

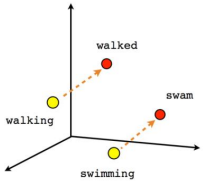
Traditional Method - Bag of Words Model	Word Embeddings
• Uses one hot encoding • Each word in the vocabulary is represented by one bit position in a HUGE vector. • For example, if we have a vocabulary of 10000 words, and "Hello" is the 4th word in the dictionary, it would be represented by: 0 0 0 1 0 0 . . . . . 0 0 0 0 • Context information is not utilized	• Stores each word in as a point in space, where it is represented by a vector of fixed number of dimensions (generally 300) • Unsupervised, built just by reading huge corpus • For example, "Hello" might be represented as : [0.4, -0.11, 0.55, 0.3 . . . 0.1, 0.02] • Dimensions are basically projections along different axes, more of a mathematical concept.

"A word is known by the company it keeps"

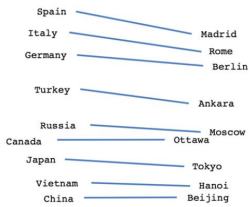
Examples



Male-Female



Verb tense



Country-Capital

vector[Queen] = vector[King] - vector[Man] + vector[Woman]

Applications of Word Vectors

5. Sentiment Analysis

Classic Methods : Naive Bayes, Random Forests/SVM

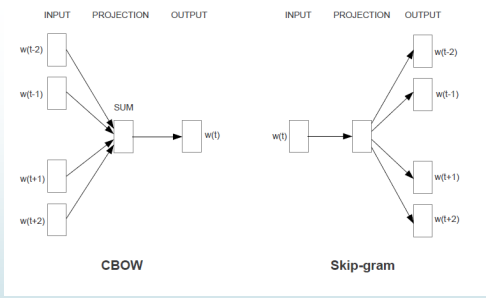
- Classifying sentences as positive and negative
- Building sentiment lexicons using seed sentiment sets
- No need for classifiers, we can just use cosine distances to compare unseen reviews to known reviews.

```
Enter word or sentence (EXIT to break): sad

Word: sad  Position in vocabulary: 4067

                                  Word       Cosine distance
--------------------------------------------------------------
                             saddening                0.727309
                                   Sad                0.661083
                              saddened                0.660439
                          heartbreaking               0.657351
                          disheartening               0.650732
                           Meny_Friedman              0.648706
                    parishioner_Pat_Patello           0.647586
                              saddens_me               0.640712
                            distressing                0.639909
                        reminders_bobbing              0.635772
                        Turkoman_Shiites               0.635577
                                 saddest               0.634651
                             unfortunate               0.627209
                                   sorry               0.619405
                             bittersweet               0.617521
                                   tragic              0.611279
                                regretful              0.603472
```

Word2Vec



- Train for word given context
- Hidden layer => Vector Embedding
- Train for context given word
- Hidden layer => Vector Embedding

Glove

GloVe: **Global Vectors for Word Representation**

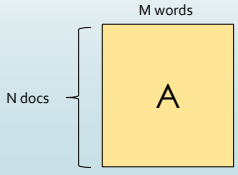
- While word2Vec is a predictive model — learning vectors to improve the predictive ability, **GloVe is a count-based model**.
- Count-based models learn vectors by doing dimensionality reduction on a **co-occurrence counts matrix**.
  - Factorize this matrix to yield a lower-dimensional matrix of words and features, where each row yields a vector representation for each word.
  - The counts matrix is preprocessed by normalizing the counts and log-smoothing them.

Benefit of Global Information

Probability and Ratio	$k = solid$	$k = gas$	$k = water$	$k = fashion$
$P(k\|ice)$	1.9×10^{-4}	6.6×10^{-5}	3.0×10^{-3}	1.7×10^{-5}
$P(k\|steam)$	2.2×10^{-5}	7.8×10^{-4}	2.2×10^{-3}	1.8×10^{-5}
$P(k\|ice)/P(k\|steam)$	8.9	8.5×10^{-2}	1.36	0.96

Old-school inspiration: Latent Semantic Analysis

- Latent semantic analysis studies documents in Bag-Of-Words model (1988).
  - i.e. given a matrix ***A*** encoding some documents: A_{ij} is the count* of word ***j*** in document ***i***. Most entries are 0.



Co-occurrence Matrix using Windows

Example corpus: (R. Socher)
- I like deep learning.
- I like NLP.
- I enjoy flying.

What's the window size here?

counts	I	like	enjoy	deep	learning	NLP	flying	.
I	0	2	1	0	0	0	0	0
like	2	0	0	1	0	1	0	0
enjoy	1	0	0	0	0	0	1	0
deep	0	1	0	0	1	0	0	0
learning	0	0	0	1	0	0	0	1
NLP	0	1	0	0	0	0	0	1
flying	0	0	1	0	0	0	0	1
.	0	0	0	0	1	1	1	0

Wider Windows

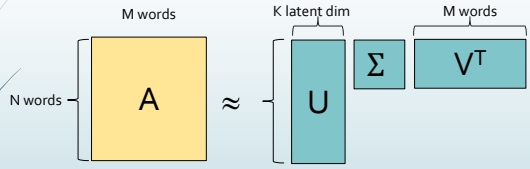
- "I find that computer science is awesome"
- X(I, find) += 1
- X(I, that) += .5
- X(I, computer) += .33
- Etc…

Vectorizing Co-occurrence Matrices

counts	I	like	enjoy	deep	learning	NLP	flying	.
I	0	2	1	0	0	0	0	0
like	2	0	0	1	0	1	0	0
enjoy	1	0	0	0	0	0	1	0
deep	0	1	0	0	1	0	0	0
learning	0	0	0	1	0	0	0	1
NLP	0	1	0	0	0	0	0	1
flying	0	0	1	0	0	0	0	1
.	0	0	0	0	1	1	1	0

- Vectors too big!
- Classic Solution - Solution SVD (Singular Value Decomposition)

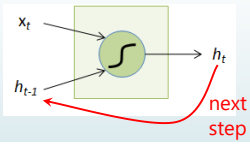
Singular value decomposition



Elmo

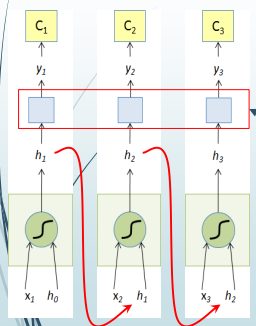
The Recurrent Neuron

- x_t: Input at time t
- h_{t-1}: State at time t-1



$$h_t = f(W_h h_{t-1} + W_x x_t)$$

Unfolding an RNN



$$h_t = f(W_h h_{t-1} + W_x x_t)$$

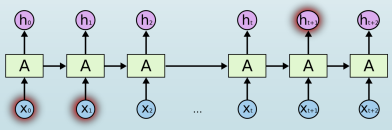
Weights shared over time!

Vanishing/Exploding Gradient Problem

- Backpropagated errors multiply at each layer, resulting in exponential decay (if derivative is small) or growth (if derivative is large).
- Makes it very difficult train deep networks, or simple recurrent networks over many time steps.

Long Distance Dependencies

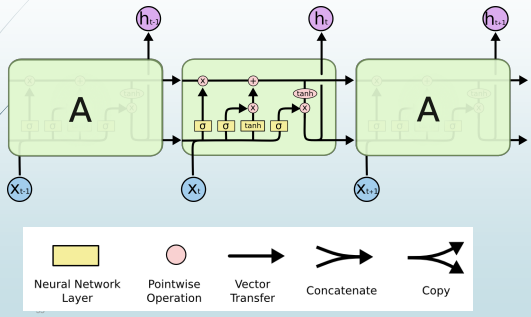
- It is very difficult to train simple recurrent networks (SRN) to retain information over many time steps
- This make is very difficult to learn SRNs that handle long-distance dependencies, such as subject-verb agreement.



Long Short Term Memory

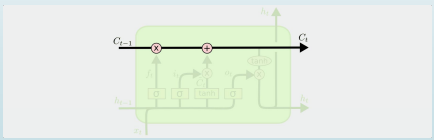
- LSTM networks, add additional gating units in each memory cell.
  - Forget gate
  - Input gate
  - Output gate
- Prevents vanishing/exploding gradient problem and allows network to retain state information over longer periods of time.

LSTM Network Architecture



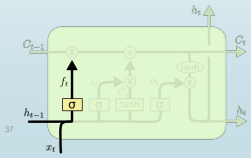
Cell State

- Maintains a vector C_t that is the same dimensionality as the hidden state, h_t
- Information can be added or deleted from this state vector via the forget and input gates.



Forget Gate

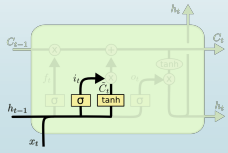
- Forget gate computes a 0-1 value using a logistic sigmoid output function from the input, x_t, and the current hidden state, h_t:
- Multiplicatively combined with cell state, "forgetting" information where the gate outputs something close to 0.



$$f_t = \sigma\left(W_f \cdot [h_{t-1}, x_t] \; + \; b_f\right)$$

Input Gate

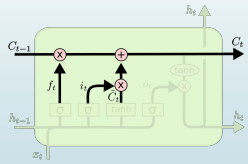
- First, determine which entries in the cell state to update by computing 0-1 sigmoid output.
- Then determine what amount to add/subtract from these entries by computing a tanh output (valued –1 to 1) function of the input and hidden state.



$$i_t = \sigma\left(W_i \cdot [h_{t-1}, x_t] \; + \; b_i\right)$$
$$\tilde{C}_t = \tanh(W_C \cdot [h_{t-1}, x_t] \; + \; b_C)$$

Updating the Cell State

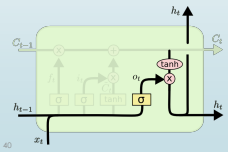
- Cell state is updated by using component-wise vector multiply to "forget" and vector addition to "input" new information.



$$C_t = f_t * C_{t-1} + i_t * \tilde{C}_t$$

Output Gate

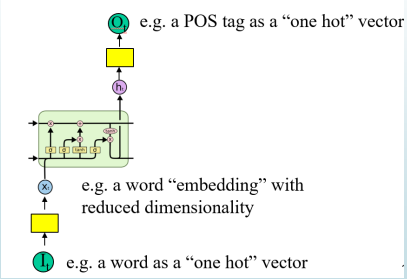
- Hidden state is updated based on a "filtered" version of the cell state, scaled to –1 to 1 using tanh.
- Output gate computes a sigmoid function of the input and current hidden state to determine which elements of the cell state to "output".



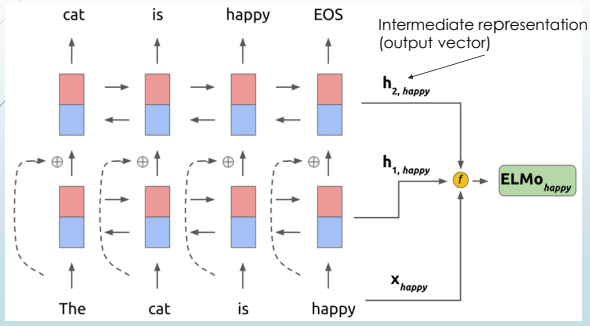
$$o_t = \sigma\left(W_o \; [h_{t-1}, x_t] \; + \; b_o\right)$$
$$h_t = o_t * \tanh\left(C_t\right)$$

Overall Network Architecture

- Single or multilayer networks can compute LSTM inputs from problem inputs and problem outputs from LSTM outputs.



ELMo: Embeddings from Language Models

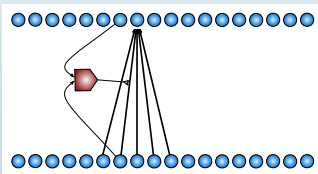


Bert

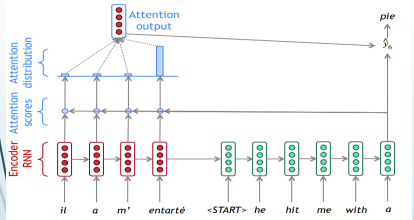
Attention Mechanism for Deep Learning

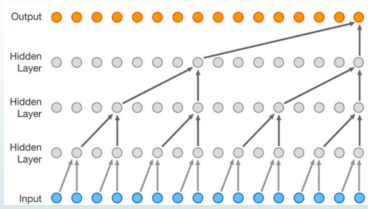
- Consider an input (or intermediate) sequence or image
- Consider an upper level representation, which can choose « where to look », by assigning a weight or probability to each input position, applied at each position

Softmax over lower locations conditioned on context at lower and higher locations



Attention



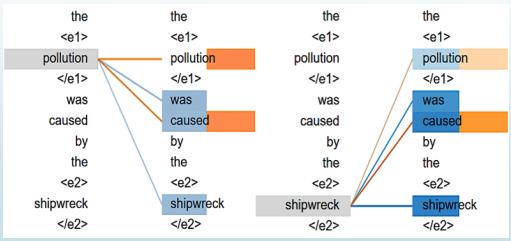


$$A(q,K,V) = \sum_i \frac{e^{q \cdot k_i}}{\sum_j e^{q \cdot k_j}} v_i$$

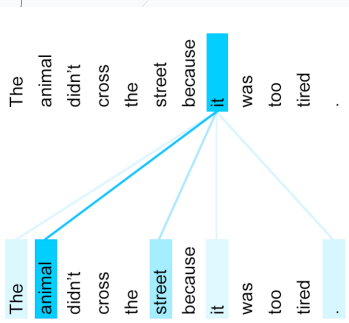
Becomes: $A(Q,K,V) = softmax(QK^T)V$

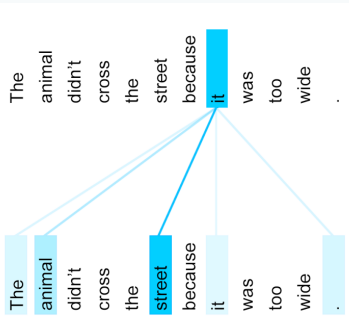
$$\text{Attention}(Q,K,V) = \text{softmax}(\frac{QK^T}{\sqrt{d_k}})V$$

In the real world



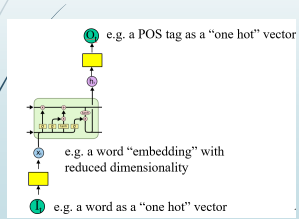
In the real world





Transformers

- A novel NN architecture based on attention
- Highly engineered
- Higlhy parallel



VS

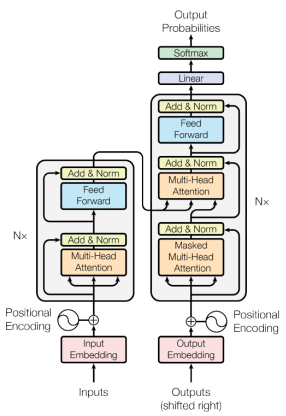


Figure 1: The Transformer - model architecture.

Bert is Bidirectional and Highly Parallel

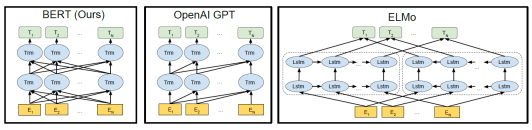


Figure 3: Differences in pre-training model architectures. BERT uses a bidirectional Transformer. OpenAI GPT uses a left-to-right Transformer. ELMo uses the concatenation of independently trained left-to-right and right-to-left LSTMs to generate features for downstream tasks. Among the three, only BERT representations are jointly conditioned on both left and right context in all layers. In addition to the architecture differences, BERT and OpenAI GPT are fine-tuning approaches, while ELMo is a feature-based approach.

- Comparing approaches

Pretrained and then Fine Tuned

- KEY IDEA:
  - Pretrain on 2 unsupervised techniques
    - Masks (MLM)
    - NextSentence
  - Then Fine tune top layer for task at hand
    - Its QUICK and Effective

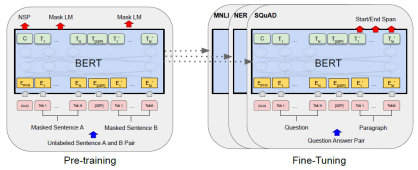
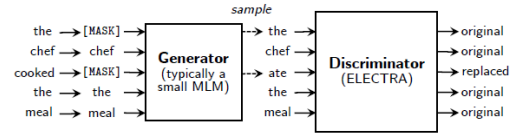


Figure 1: Overall pre-training and fine-tuning procedures for BERT. Apart from output layers, the same architectures are used in both pre-training and fine-tuning. The same pre-trained model parameters are used to initialize models for different down-stream tasks. During fine-tuning, all parameters are fine-tuned. [CLS] is a special symbol added in front of every input example, and [SEP] is a special separator token (e.g. separating questions/answers).

Electra

Electra: A Simple Enhancement



- Introduce Discriminator on top of MLM
- Decide whether word is masked for each word
- Impact: Applies loss function throughout network for every word not just masked words
  - More intelligence 'embedded' in network

GPT3

Bert: Not a fancy model (relatively speaking)

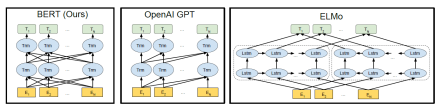
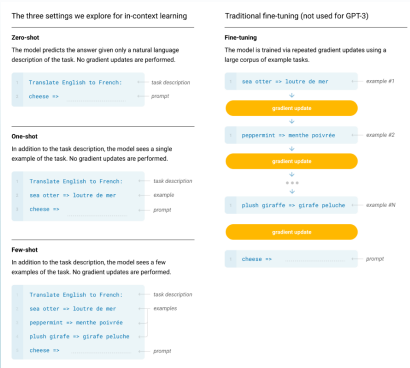


Figure 3: Differences in pre-training model architectures. BERT uses a bidirectional Transformer. OpenAI GPT uses a left-to-right Transformer. ELMo uses the concatenation of independently trained left-to-right and right-to-left LSTMs to generate features for downstream tasks. Among the three, only BERT representations are jointly conditioned on both left and right context in all layers. In addition to the architecture differences, BERT and OpenAI GPT are fine-tuning approaches, while ELMo is a feature-based approach.

- Build on GPT (not as fancy as Bert)
- Simple pretraining: Predict the next word

On the job non-training :-P

- Instead of Fine Tuning use
  - Zero Shot,
  - One Shot,
  - Few Shot



GO BIG OR GO HOME

Model Name	n_{params}	n_{layers}	d_{model}	n_{heads}	d_{head}	Batch Size	Learning Rate
GPT-3 Small	125M	12	768	12	64	0.5M	6.0×10^{-4}
GPT-3 Medium	350M	24	1024	16	64	0.5M	3.0×10^{-4}
GPT-3 Large	760M	24	1536	16	96	0.5M	2.5×10^{-4}
GPT-3 XL	1.3B	24	2048	24	128	1M	2.0×10^{-4}
GPT-3 2.7B	2.7B	32	2560	32	80	1M	1.6×10^{-4}
GPT-3 6.7B	6.7B	32	4096	32	128	2M	1.2×10^{-4}
GPT-3 13B	13.0B	40	5140	40	128	2M	1.0×10^{-4}
GPT-3 175B or "GPT-3"	175.0B	96	12288	96	128	3.2M	0.6×10^{-4}

Table 2.1: Sizes, architectures, and learning hyper-parameters (batch size in tokens and learning rate) of the models which we trained. All models were trained for a total of 300 billion tokens.

- GPT is orders of magnitude bigger than anything we've seen before

Bert: Worth $1 Billion Dollars?*

- Major Impact
- Shocking Results
- MS drops significant $$$ for it
  - *technically an 'investment' in Open AI that includes exclusive license

University of Michigan
Fall 2020 Instructor Report With Comments
EECS 498-006: Special Topics
Jason Mars

16 out of 31 students responded to this evaluation.

Responses to University-wide questions about the course:

	SA	A	N	D	SD	N/A	Your Median	Univ-wide Median	School/College Median
This course advanced my understanding of the subject matter. (Q1631)	10	6	0	0	0	0	4.7	4.6	4.5
My interest in the subject has increased because of this course. (Q1632)	10	5	1	0	0	0	4.7	4.2	4.2
I knew what was expected of me in this course.(Q1633)	12	3	0	1	0	0	4.8	4.5	4.4
Overall, this was an excellent course.(Q1)	11	5	0	0	0	0	4.8	4.4	4.3
I had a strong desire to take this course.(Q4)	12	3	1	0	0	0	4.8	4.1	4.1
As compared with other courses of equal credit, the workload for this course was (SA=Much Lighter, A=Lighter, N=Typical, D=Heavier, SD=Much Heavier). (Q891)	3	2	11	0	0	0	3.2	2.9	2.8
How did you participate in this course? (Q1854)	15	1	0	0	0	0	5.0	4.7	4.5

Responses to University-wide questions about the instructor:

	SA	A	N	D	SD	N/A	Your Median	Univ-wide Median	School/College Median
Overall, Jason Mars was an excellent teacher.(Q2)	12	4	0	0	0	0	4.8	4.7	4.7
Jason Mars seemed well prepared for class meetings.(Q230)	13	3	0	0	0	0	4.9	4.8	4.7
Jason Mars explained material clearly.(Q199)	12	4	0	0	0	0	4.8	4.7	4.7
Jason Mars treated students with respect.(Q217)	13	3	0	0	0	0	4.9	4.9	4.8

Responses to questions about the course:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median
Prerequisites provided adequate preparation for this course. (Q61)	10	3	0	2	0	1	4.8	4.5
The textbook made a valuable contribution to the course. (Q64)	4	2	1	2	0	7	4.3	3.9
I felt included and valued when working with other students. (Q253)	11	3	0	1	1	0	4.8	4.7
I felt comfortable asking questions in class. (Q521)	12	2	2	0	0	0	4.8	4.4
I developed confidence in my abilities as an engineer. (Q1769)	10	5	1	0	0	0	4.7	4.2
I developed the ability to solve real world engineering problems. (Q1770)	11	4	1	0	0	0	4.8	4.2

The medians are calculated from Fall 2020 data. University-wide medians are based on all UM classes in which an item was used. The school/college medians in this report are based on classes that are upper division with enrollment of 16 to 74 in College of Engineering.

Written Comments

Given the format of the course (e.g., fully online, in-person, etc.), what teaching methods worked well? (Q1855)

Comments
fully online was most convenient
fully online. Fully online works well.
Lectures we're good and online meetings we're easier to organize because we didn't all have to organize a time to meet somewhere in person.
I think the beginning parts of the course were really well done, and I think that the projects are interesting.
Fully online. Demos and discussions
The group presentations for papers helped with breaking down the papers into easy to comprehend information.
liked the papers
Fully online works very well.
Loved the long periods to work on projects. More professor office hours / structure in lectures might have been useful.
I really liked having the students present on papers, while not presenting on all of them. This helped facilitate deep understanding, while also a balanced workload.
The zoom lecturing and presentations were good.

What were the greatest challenges to your learning in this course format? (Q1856)

Comments
difficult to feel as immersed in class due to online as the content can be very difficult but interesting as well.
We talk about the cutting–edge research in lectures,but we use existing tools like DialogFlow, Amazon Lex to build our projects. Concepts in lectures are being forgotten quite quickly.
Staying fully engaged
I think there needs to be more about what to do for projects baked into this course. My team did not communicate very well, and ended up making a project that I do not feel very confident in. I think there should be some guidance for helping teams with their ideas early on, because my team realistically did not communicate well and had a few members who did not contribute much code, so we ended up cobbling something together last minute.
cannot attend OH in person
Working with a large group remotely posed challenges since the entire class is group work based.
N/A
no
N/A
Working in teams remotely is always difficult, as you never get to meet your teammates in person and make small talk.
Group collaboration virtually.

Comment on the quality of instruction in this course. (Q900)

Comments
jason mars is a very smart guy and knows what he's talking about
Instruction was very good. Professor Mars knows a lot about the technical aspects of the topics and also knows the industry and the products/research going on within it
Great.
Professor Mars was a great lecturer and his enthusiasm was inspiring for building a chat bot.
Good
Excellent
Jason Mars is both enthusiastic and knowledgeable about the material covered. Although some lectures can move fast over a large amount of ML concepts, they cover a lot of what gets used in the class.
excellent
This class is amazing and outstanding!!! Professor Mars covered all the important details about each NLP paper we read and helped us to develop a well–rounded and solid understanding of NLP. I enjoyed every single class and always learned new things. Professor Mars also talked about the connections between each paper and they helped me build a more systematic understanding. From my perspective, this class is the best MDE course at Umich, definitely one of my favorite classes I took at Umich. We got the chance to explore what we are interested in, and Professor Mars always tries his best to help us either on project or NLP theory. He also discussed small details of our project and always inspired my team members and me. Finally, I think this class should become a normal MDE course because it is fabulous.
Instruction was great.
This course was fantastic! Really great MDE course in my opinion.
Instruction was meaningful but sometimes confusing.

How might the class climate be made more inclusive of diverse students? (Q910)

Comments
its as good as it gets, always difficult since there is a range of experiences in this class
I thought there was no obvious issue with this.
None
I think at the moment the class is pretty inclusive of diverse students, I'm not really sure I have any productive suggestions for this one.
Not sure group work already does that
more students attending courses synchronously
The class climate could be made more inclusive with more group discussions at the beginning to help students find others to work with.
no comment
It is already perfect.
N/A
I think it was already very inclusive and everyone was treated equally.
There were only 2 girls total in the course, which I wish they improved on. My entire team was 5 boys and myself.
Nothing about this class is different as far as inclusion than any other EECS class.

What were the strengths of the course ? (Q953)

Comments
very interesting field of AI to learn about so it is easy to get interested
Compared to other MDE class, I think this MDE course is the only one that provides a deep insight into a specific field, instead of grading only by projects.
The topic of Conversational AI is a very good one for an MDE because there are so many tools for it that make student's able to create reasonably–scoped but also very interesting/innovative projects.
Intensive paper readings
Like I mentioned earlier, I think the first few weeks of lecture were very strong, and I think that the project has a lot of potential, but I think it should maybe be less open ended in the future so that groups don't slip through the cracks like I feel mine did.
Learning by doing
capstone design, important undergraduate experience
The course emphasized practical applications which gave a lot of experience on the production and implementation side of coding.
papers, prof made himself available to help
1. a systematic understanding of NLP 2. read state of art papers 3. MDE project: working on things we are interested in 4. Professor Mars
Long project format was perfect. An emphasis on starting early would have been nice.
Great content, and a wide range of possibilities for projects.
First hand experience with AI implementations.

What suggestions would you make for improving the course ? (Q955)

Comments
a little refresher on developing web applications
Building (part of) projects using the techniques introduced in lectures.
Although Prof Mars made it very clear we could set up meetings with him at any time, more office hours/times pre–designated for meetings would have been nice. One slot on Mondays (before the week's two lectures) leaves a pretty narrow window.
None
A more comprehensive look at a past project that was done well to give students a better idea of what to do for their project. I think my group set some goals that were not very realistic and then had to fall back on a pretty limited set of features for the final project, and if we had had a better idea early on of what we should be doing we may have been able to achieve more.
N/A
add coding tasks as homework for implementation of NLP models mentioned in class
I would remove one of the paper presentations and replace it with a presentation or workshop on specific features in the overall MDE project.
None, great course
nothing
Start the projects earlier and have a couple more sessions on brainstorming/technical solutions to problems.
More regular touchpoints with teams to ensure steady progress and to bounce ideas off of the professor.
More actual code examples along side the main projects.

Among the courses you have already taken, which proved the most (or least) effective in preparing you for this course, and why? (Q1098)

Comments
eecs 485 gives you knowledge on flask and react that have become very handy.
EECS485. EECS485 project 2 and 3 taught us how to build an instagram front–end and back–end. And in this course we need to build a conversational AI assistant, also consisting front–end and back–end.
EECS 281 I guess (hadn't taken any upper levels before this), but other than code design principles and algorithms I learned in EECS 281, most of what was necessary was obtained from internships and student teams (Python, APIs, git)
Preview
I think that EECS 485 was extremely important for this class, as a lot of the coding I have done has required the use of a REST API, or required me to use python.
Internships, 281, and 485 most effective
EECS 281. Being able to learn new programming language fast with strong foundation of C++.
EECS 445 ML was the most effective since it covered the ML content needed to understand the conversational A.I. in the class.
ML and projects on my own building full stack applications
EECS445
445 is essential as is 281 of course. I would also recommend some full–stack experience.
EECS 445 was really helpful to have some background in ML, aside from that, 485 is really helpful for background in building app interfaces.
281 maybe

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-11-04
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Elec Engin & Computer Sci Subject: EECS Catalog: 471
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Applied Parallel Programming with GPUs
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Applied GPU Prog
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Parallel computing and application development for massively parallel processors such as GPUs. Focuses on forms of parallelism, programming models such as CUDA, mapping computations to parallel hardware, efficient data structures, and paradigms for efficient parallel algorithms. Students will gain hands-on experience in programming assignments and projects.	
☑	Full Term Credit Hours Undergraduate Min: 4 Graduate Min: 4 Undergraduate Max: 4 Graduate Max: 4	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Undergraduate Student, Rackham Graduate Student, Non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char)
☑	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) EECS 281 and 370; (C or better, No OP/F) or Graduate Standing in CSE Minimum grade requirement: C
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☑ Discussion ☐ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered ☑ Fall ☐ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Reetuparna Das	Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative:		Print:	Amir Kamil	Date:	11/12/21
CoE Curriculum Committee Chair:		Print:		Date:	
Home Department Chair:		Print:	Amir Kamil	Date:	11/12/21
Cross-Listed Department Chair:		Print:		Date:	
Cross-Listed Department Chair:		Print:		Date:	
Cross-Listed Department Chair:		Print:		Date:	

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Parallel computing and application development for massively parallel processors such as GPUs. Focuses on forms of parallelism, programming models such as CUDA, mapping computations to parallel hardware, efficient data structures, and paradigms for efficient parallel algorithms. Students will gain hands-on experience in programming assignments and projects.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation) 1
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
The proposed course will satisfy the growing needs of undergraduate students to understand parallel computing in practice and develop parallel applications. Parallel computing is pervasive. GPUs have become the de-facto choice for a large fraction of parallel computing applications, finding their place in mobile platforms to clouds and supercomputers. Self-driving cars, machine learning, and augmented reality are examples of applications involving parallel computing. The course has sufficient breadth and depth for an upper-level CS class. It covers a popular parallel programming interface (CUDA for NVIDIA GPUs), internal architecture of graphics processors and how it impacts performance, and implementations of parallel algorithms on massively parallel processors. The class has heavy programming components, including six hands-on assignments and a final project. Previous offerings of this class in the form of independent special topics courses have seen significant interest from the undergraduate student population. The combined enrollment across EECS 498/598 has steadily grown from 52 students in Fall 2019 to 89 students in Fall 2021. Similar undergraduate course offerings at other universities (e.g., Stanford, UIUC) also have large enrollments. This course is intended to fulfill a ULCS elective requirement for CS-LSA and CS-Eng majors.

Past offerings:

Fall 2019: 52 students (21 in EECS 498, 31 in EECS 598)
Fall 2020: 74 students (40 in EECS 498, 34 in EECS 598)
Fall 2021: 89 students (42 in EECS 498, 47 in EECS 598)

EECS 498/598: APPLIED PARALLEL PROGRAMMING WITH GPUS

FALL 2021

ANNOUNCEMENTS

COURSE OVERVIEW

LECTURES

DISCUSSIONS

STAFF AND HOURS

RESOURCES

ASSIGNMENTS

FINAL PROJECT

EXAMS

ADMINISTRATIVE REQUESTS

PIAZZA

Course Overview

The goal of this class is to teach parallel computing and developing applications for massively parallel processors (e.g. GPUs). Selfdriving cars, machine learning and augmented reality are examples of applications involving parallel computing. The class focuses on computational thinking, forms of parallelism, programming models, mapping computations to parallel hardware, efficient data structures, paradigms for efficient parallel algorithms, and application case studies.

The course will cover popular programming interface for graphics processors (CUDA for NVIDIA processors), internal architecture of graphics processors and how it impacts performance, and implementations of parallel algorithms on graphics processors. The curriculum will be delivered in ~29 lectures. The class has heavy programming components, including five handson assignments and a final project.

Prerequisites

Students must have taken both EECS 281 and EECS 370

UG Requirements met by the class:

4 credits, Upper-level elective for CS and CE majors, Flex Tech electives.

Programming Assignments

Five assignments will be assigned during the term.

The most common reason for not doing well on the assignments is not starting them early enough. You will be given plenty of time to complete each assignment. However, if you wait until the last minute to start, you may not be able to finish. Plan to have it finished about 2 days ahead of the due date - many unexpected problems arise during programming, especially in the debugging phase. Plan for these things to happen. Your lack of starting early is not an excuse for turning in your assignment late, even if some unfortunate situations arise such as having your computer crash.

There are many sources of help on which you can draw. Many questions can be submitted to the course staff and your fellow classmates via the class forum. The policies for using the class forum are contained in the first post in the forum. These will typically be answered within the day, often more quickly during working hours. However, some types of questions cannot be answered without seeing your code. If you have detailed questions on your program, speak to a IA or professor in office hours.

Students are also encouraged to help one another on the course concepts (but not the implementation of the assignments). One of the best ways for you to make sure that you understand a concept is to explain it to someone else. Keep in mind, however, that you should not expect anyone else to do any part of your programming assignment for you. *The programming assignment that you turn in must be completely your own.*

Turning in Assignments

Assignments are due at 11:59 pm exactly on the due date.

Each assignment has a programming component to be submitted on Great Lakes, and a quiz component to be submitted on Gradescope. The programming component is 80% of the assignment grade, and the quiz component is 20% of the assignment grade.

Final Project

There will be a final project with an open ended implementation. You will be responsible for using the knowledge you gained throughout the course to optimize an applied problem. Project details will be posted later in the term.

Assignment and Project Grading

The assignments and project will be graded on both correctness and performance. All grading questions should first be discussed with your IA. If you cannot resolve a problem with the IA, bring the project to the instructor.

Doing Your Own Assignments

All assignments and exams in this course are to be done on your own, with the exception of the final project where you will be allowed to have a partner. Any suspected violation will result in the initiation of formal procedures with the LS&A or Engineering Honor Council. Violators will receive a 0 in the assignment,

in addition to additional grade repercussions, as recommended by the appropriate Honor Council.

We will be using a sophisticated automated program to correlate programming work, including those submitted in previous semesters.

We do encourage students to help each other learn the course material. As in most courses, there is a boundary separating these two situations. You may give or receive help on any of the concepts covered in lecture or discussion and on the specifics of CUDA syntax. You are allowed to consult with other students in the current class to help you understand the assignment specification (i.e. the problem definition). However, you may not collaborate in any way when constructing your solution - the solution to the assignment must be generated by your work alone and the work of other students must **not** have contributed to your solution. You are not allowed to work out the programming details of the problems with anyone or to collaborate to the extent that your programs are identifiably similar. You are not allowed to look at or in any way derive advantage from the existence of specifications or solutions prepared in prior years (e.g. programs written by former students, solutions provided by instructors, or handouts).

If you have any questions as to what constitutes unacceptable collaboration, please talk to the instructor right away. You are expected to exercise reasonable precautions in protecting your own work. Do not leave your program in a publicly accessible directory, and take care when discarding printouts.

Exams

There will be **two** exams this semester. You are expected to take the exams at the scheduled times. If you do not take an exam without verifying a documented medical or personal emergency causing you to miss an exam, you will receive a zero for that exam. If you anticipate conflicts with the exam time, declare your conflicts **by 9/30/2020**. The exam dates are given near the beginning of the semester so you can avoid scheduling job interviews or other commitments on exam days. Outside commitments are not considered a valid reason for missing an exam. If you need to request any special accommodation during any exam, please bring the necessary paperwork from the SSD office by the end of the first month of classes.

Grading Policy

Final grades will be based on the total points earned on homeworks, programming assignments and exams. Factors such as class participation may be used to adjust your final grade, especially if it falls on a borderline. The grade distribution is

different for the undergraduate and graduate students, i.e., those who have taken EECS 498 and 598, respectively. We consider the following grading policies:

EECS 498 Students:

- Programming Assignments = 50%
- Final Project = 15%
- Midterm = 15%
- Final exam = 20%

EECS 598 Students:

- Programming Assignments = 50%
- Final Project = 20%
- Midterm = 15%
- Final exam = 15%

Incompletes will generally not be given. According to university policy, doing poorly in a course is not a valid reason for an incomplete. If you are having problems in the course, your best bet is to come talk to the instructor as soon as you are aware of them.

Lecture Schedule : Lectures

Date	Lecture	Topic (Lecture recording hyperlinked)	Readings	Assignments Due
Aug 30	1	Introduction	Chapter 1	
Sep 1	2	Introduction to CUDA C and Data Parallel Programming	Chapter 2	
Sep 6		Labor day		
Sep 8	3	Kernel-Based Data Parallel Execution Model	Chapter 3	FIRST Discussion section on 9/10
Sep 13		No Lecture		
Sep 15	4	Memory Model and Locality	Chapter 4	Assignment 1 DUE (Vector Addition) (9/17)
Sep 20	5	Memory Model and Locality -2	Chapter 5	
Sep 22	6	DRAM, Shared Memory, Coalescing	Chapter 5	Assignment 2 DUE (Naive Matrix Multiplication) (9/24)
Sep 27	7	Shared Memory, Convolution	Chapter 7	
Sep 29	8	Convolution, Constant Memory and Tiled Convolution	Chapter 7	Assignment 3 DUE (Tiled Matrix Multiplication) (10/1)
Oct 4	9	Parallel Computation Patterns – Reduction Trees 1	Chapter 5	
Oct 6	10	Midterm Exam review		
Oct 11		Midterm		
Oct 13	11	Parallel Computation Patterns – Reduction Trees 2	Chapter 5	Assignment 4 DUE (3D Convolution) (10/15)
Oct 18		Fall Break		
Oct 20	12	Parallel Computation Patterns – Parallel Scan (Prefix Sum)		
Oct 25	13	Atomic Operations and Histogramming	Chapter 8	
Oct 27	14	Parallel Sparse Methods - 1	Chapter 9	Assignment 5 DUE (List Reduction) (10/29)
Nov 1	15	Parallel Sparse Methods - 2	Chapter 10	
Nov 3	16	Host and GPU Interactions, Streams	Chapter 10	Final Project RELEASED (11/3)
Nov 8	17	GPU Microarchitecture, Floating Point Considerations & Profiling	Chapter 13, Chapter 6	
Nov 10	18	Application Case Study – Deep Learning	Chapter 16	Assignment 7 DUE (Histogram Equalization) (11/12)
Nov 15	19	Application Case Study – Deep Learning, Part 2	Chapter 16	
Nov 17	20	OpenCL and Art of Parallel Programming		
Nov 22		Thanksgiving		
Nov 24		Thanksgiving		
Nov 29	21	Summary and Future Directions		
Dec 1	22	Guest Lecture		
Dec 6		No Lecture		Final Project DUE (12/7)
Dec 8	24	Final Exam Review, Prize Distribution		
Dec 16		Final Exam		

EECS 498/598

Final Project

Due date: December 4, 2020 11:59pm

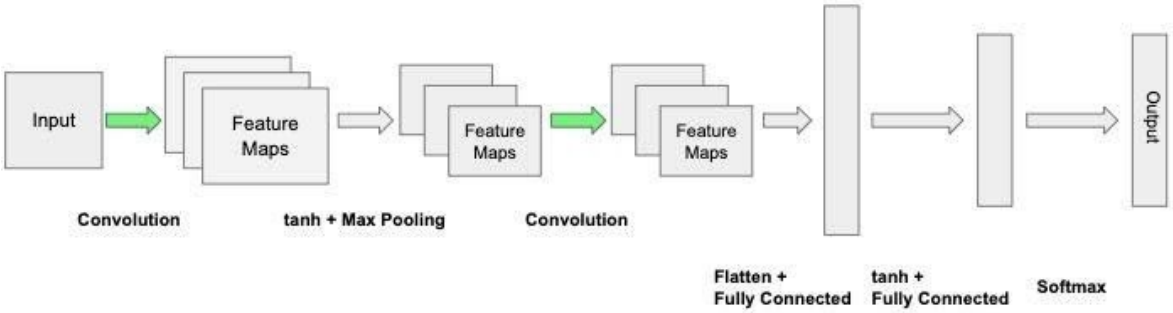
Introduction

- Get practical experience by using, profiling, and modifying MXNet, a standard open-source neural-network framework.

- Demonstrate command of CUDA and optimization approaches by designing and implementing an optimized neural-network convolution layer forward pass.

For a background and introduction to Convolutional Neural Networks we suggest this video.

You will be using a pretrained CNN to predict images from the MNIST-Fashion dataset. The starter code given to you is a correct implementation of the convolution layers and your optimized versions should have identical functionality.



You must implement and document at least **2** optimizations.

Grading

70% correctness and speed

- Correctness: you must have 0.7955 to receive any points on the project

-Speed: you are expected to achieve under 2 seconds for both layers combined

-Your implementation must match the same functionality as the starter code, you will receive 0 points for an incorrect implementation.

30% final project report

-See final report section for what is expected from you.

Set up

You will be developing on great lakes.

Run the following two commands in sequence to pull the code for the final project into your personal workspace and setup (note, this may take a while):
tar -xzvf /scratch/eecs498f20_class_root/eecs498f20_class/shared_data/final_project.tar.gz

python get-pip.py --user

Directory Layout

Once you pull the code into your workspace, there will be a folder named “final_project” with the following items

final_project

-fashion-mnist (d)
-incubator-mxnet (d)
-models (d)
-submit (d)
-new-forward.cuh (f)
-run_student.sh (f)
-run_mxnet_student.sh (f)
-build_student.sh (f)
-get-pip.py (f)

fashion-mnist contains images from the fashion-mnist dataset that your CNN will be classifying.

incubator-mxnet contains the source code for the mxnet library, the code you write will be compiled into this with your custom implementation.

models contains a JSON description of a pretrained CNN that will use your implementation of the forward pass convolution layer to classify the fashion-mnist images.

submit contains a python script that you will use to run your CNN, submission.py, as well as a submit_code script that you will use to submit your code for grading.

new-forward.cuh is the only file that you should be modifying. We have provided scripts to help you with running your code. Run **./build_student.sh** to compile your source code into mxnet, which will allow you to run your implementation by running **./run_student.sh**. The profiling info (including timing) will be available in the generated slurm output.

To submit your code, simply run `**./submit/submit_code <new_forward.cuh>** `**.** This will copy your file into the **all_sub** folder, similar to how your other assignments were submitted.

You will be graded based on what source code you have submitted via the submission script in great lakes. Make sure that you have your final, working version there at the time of the deadline, as only the latest version will be graded

Optimizations

You must implement at least 2 optimizations to the forward pass convolutional layer. You have starter code of an extremely naive but correct implementation in the file new-forward.cuh. You can implement the optimizations separately (i.e. they do not need to build on each other), however you must document each optimizations performance effect within your final report and be sure to keep the functions of each optimization you write within your file for your final submission. (see final report)

You are encouraged to be creative with your optimizations! Here are some suggestions that you could consider, but feel free to implement one not included below.

Suggested optimizations:

- Shared Memory convolution
- Weight matrix (kernel values) in constant memory
- Loop unrolling
- Unroll + shared-memory Matrix multiply
- Kernel fusion for unrolling and matrix-multiplication
- Exploiting parallelism in input images, input channels, and output channels
- Multiple kernel implementations for different layer sizes
- Sweeping various parameters to find best values (block sizes, amount of thread coarsening)

Final Report
As you implement your optimizations, you are required to document their effect on performance.

Create a document and describe each optimization you implemented, including why you selected this optimization, screenshots of profiler output, and the output of each layer's timing with this optimization. Describe in detail how you implemented the optimizations.

Leaderboard and Prizes
Top 3 on the leaderboard (coming soon!) will get prizes sponsored by
https://www.kla-tencor.com/

John McLaughlin
Senior Director, Ann Arbor Site Leader

University of Michigan
Fall 2019 Instructor Report With Comments
EECS 498 003 - EECS 598 009
Reetuparna Das

25 out of 52 students responded to this evaluation.

Responses to the University-wide questions about the course:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median	School/College Median
This course advanced my understanding of the subject matter. (Q1631)	18	7	0	0	0	0	4.8	4.5	4.4
My interest in the subject has increased because of this course.(Q1632)	17	8	0	0	0	0	4.8	4.2	4.1
I knew what was expected of me in this course.(Q1633)	17	7	1	0	0	0	4.8	4.4	4.3
Overall, this was an excellent course.(Q1)	14	8	2	1	0	0	4.6	4.2	4.2
I had a strong desire to take this course.(Q4)	19	6	0	0	0	0	4.8	4.0	4.1
As compared with other courses of equal credit, the workload for this course was...(SA=Much Lighter to SD=Much Heavier) (Q891)	4	10	10	1	0	0	3.7	3.0	2.8

Responses to University-wide questions about the instructor:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median	School/College Median
Overall, Reetuparna Das was an excellent teacher. (Q2)	12	8	5	0	0	0	4.4	4.6	4.5
Reetuparna Das seemed well prepared for class meetings.(Q230)	13	9	2	1	0	0	4.5	4.8	4.7
Reetuparna Das explained material clearly.(Q199)	12	7	6	0	0	0	4.4	4.6	4.6
Reetuparna Das treated students with respect.(Q217)	18	7	0	0	0	0	4.8	4.8	4.8

Responses to additional questions about the course:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median
Prerequisites provided adequate preparation for this course. (Q61)	15	9	0	0	0	1	4.7	4.3
The textbook made a valuable contribution to the course. (Q64)	11	5	3	1	0	4	4.6	3.6
I developed confidence in my abilities as an engineer. (Q1769)	12	8	3	0	0	0	4.5	4.1
I developed the ability to solve real world engineering problems. (Q1770)	15	9	1	0	0	0	4.7	4.1
The discussion section was a valuable part of this course. (Q1771)	8	6	4	5	0	2	3.9	4.0

The medians are calculated from Fall 2019 data. University-wide medians are based on all UM classes in which an item was used. The school/college medians in this report are based on classes that are upper division with enrollment of 16 to 74 in College of Engineering.

University of Michigan
Fall 2020 Instructor Report Without Comments
EECS 498 003 - EECS 598 009
Reetuparna Das

22 out of 70 students responded to this evaluation.

Responses to University-wide questions about the course:

	SA	A	N	D	SD	N/A	Your Median	Univ-wide Median	School/College Median
This course advanced my understanding of the subject matter. (Q1631)	13	8	0	0	0	0	4.7	4.6	4.5
My interest in the subject has increased because of this course. (Q1632)	12	7	2	0	0	0	4.6	4.2	4.2
I knew what was expected of me in this course.(Q1633)	10	8	2	1	0	0	4.4	4.5	4.4
Overall, this was an excellent course.(Q1)	8	9	3	1	0	0	4.2	4.4	4.3
I had a strong desire to take this course.(Q4)	11	9	0	0	0	0	4.6	4.1	4.1
As compared with other courses of equal credit, the workload for this course was (SA=Much Lighter, A=Lighter, N=Typical, D=Heavier, SD=Much Heavier). (Q891)	2	7	11	1	0	0	3.4	2.9	2.8
How did you participate in this course? (SA=Attended most synchronously, A=Attended most asynchronously, N=Attended most in person, D=Attended some in person and some online). (Q1854)	11	10	0	0	0	0	4.5	4.7	4.5

Responses to University-wide questions about the instructor:

	SA	A	N	D	SD	N/A	Your Median	Univ-wide Median	School/College Median
Overall, Reetuparna Das was an excellent teacher.(Q2)	8	9	3	1	0	0	4.2	4.7	4.6
Reetuparna Das seemed well prepared for class meetings.(Q230)	15	4	1	0	1	0	4.8	4.8	4.7
Reetuparna Das explained material clearly.(Q199)	11	5	4	0	1	0	4.5	4.7	4.6
Reetuparna Das treated students with respect.(Q217)	18	2	1	0	0	0	4.9	4.9	4.8

Responses to questions about the course:

	SA	A	N	D	SD	N/A	Your Median	University-Wide Median
Prerequisites provided adequate preparation for this course. (Q61)	14	4	2	0	0	1	4.8	4.5
The textbook made a valuable contribution to the course. (Q64)	10	1	1	1	1	6	4.8	3.9
I felt included and valued when working with other students. (Q253)	9	3	0	0	1	7	4.8	4.7
I felt comfortable asking questions in class. (Q521)	10	6	1	0	0	2	4.7	4.4
I developed confidence in my abilities as an engineer. (Q1769)	10	8	0	1	0	1	4.6	4.2
I developed the ability to solve real world engineering problems. (Q1770)	9	9	0	1	0	1	4.4	4.2

The medians are calculated from Fall 2020 data. University-wide medians are based on all UM classes in which an item was used. The school/college medians in this report are based on classes that are upper division with enrollment of 75 or greater in College of Engineering.

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-04-28
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Elec Engin & Computer Sci Subject: EECS Catalog: 601
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Reinforcement Learning
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) ReinforceTheory
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Basic theories and principles of reinforcement learning, and model-based and model-free reinforcement learning algorithms. Topics: Value iteration, policy iteration, Q-learning, SARSA, policy-gradient, variance reduction, linear and nonlinear function approximation, deep reinforcement learning, exploration-exploitation, convergence analysis, regret analysis.	
☑	Full Term Credit Hours Undergraduate Min: Graduate Min: 3 Undergraduate Max: Graduate Max: 3	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Rackham Graduate Student, Non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) EECS 501
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☑ Lecture ☐ Seminar ☐ Recitation ☐ Lab ☐ Discussion ☐ Independent Study	Graded Component ☑ ☐ ☐ ☐ ☐ ☐	Terms Typically Offered ☑ Fall ☑ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Lei Ying	Cognizant Faculty Member Title:

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Email: Phone:

CoE Curriculum Committee Representative:	Fred L. Terry, Jr.	Print:	Fred L. Terry, Jr.	Date: 11/18/21
CoE Curriculum Committee Chair:		Print:		Date:
Home Department Chair:	Heath Hofmann	Print:	Heath Hofmann	Date: 10/26/21
Cross-Listed Department Chair:		Print:		Date:
Cross-Listed Department Chair:		Print:		Date:
Cross-Listed Department Chair:		Print:		Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Basic theories and principles of reinforcement learning, and model-based and model-free reinforcement learning algorithms. Topics: Value iteration, policy iteration, Q-learning, SARSA, policy-gradient, variance reduction, linear and nonlinear function approximation, deep reinforcement learning, exploration-exploitation, convergence analysis, regret analysis.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

ABET departmental program outcomes for undergraduate courses:
Not ABET accredited

Special resources of facilities required for this course:

Supporting statement:
This course covers basic theories and principles of reinforcement learning and popular deep reinforcement learning algorithms. Reinforcement learning has applications in artificial intelligence, machine learning, control, and communication/information networks. This course complements the existing curriculum in machine learning, control, and networks.

WN 2020: Enrollment - 76
Evaluation: Q1: 4.63, Q2:4.55, Q4:4.84, Q891:2.71

FA 2020: Enrollment - 63
Evaluation: Q1:4.00, Q2: 4.10, Q4: 4.50, Q891: 3.2

Reinforcement Learning

Prerequisites: EECS 501 (advisory)

Topics: This course covers fundamental theories and principles of reinforcement learning. Topics to be covered include:

1. Dynamic programming and the principle of optimality
2. Markov chains and Markov Decision Process (MDP)
3. Value iteration, policy iteration, and LP formulation
4. Q-Learning and SARSA
5. Temporal-difference learning
6. Linear and nonlinear function approximation
7. Deep Q-learning
8. Policy gradient algorithm and variance reduction
9. Deterministic policy gradient algorithms
10. The ODE methods and convergence analysis
11. Multi-armed bandit

Grading

- Homework and programming assignments: 50%, Mini-Project: 15%; and Final Project: 35%

Mini-Projects

- Five students will be selected randomly to form a group to work on a mini-project. The group needs to prepare a presentation to the class and submit a short report (and codes if applicable).
- Each student only needs to participate in one mini-project.

Final Project

Requirements:

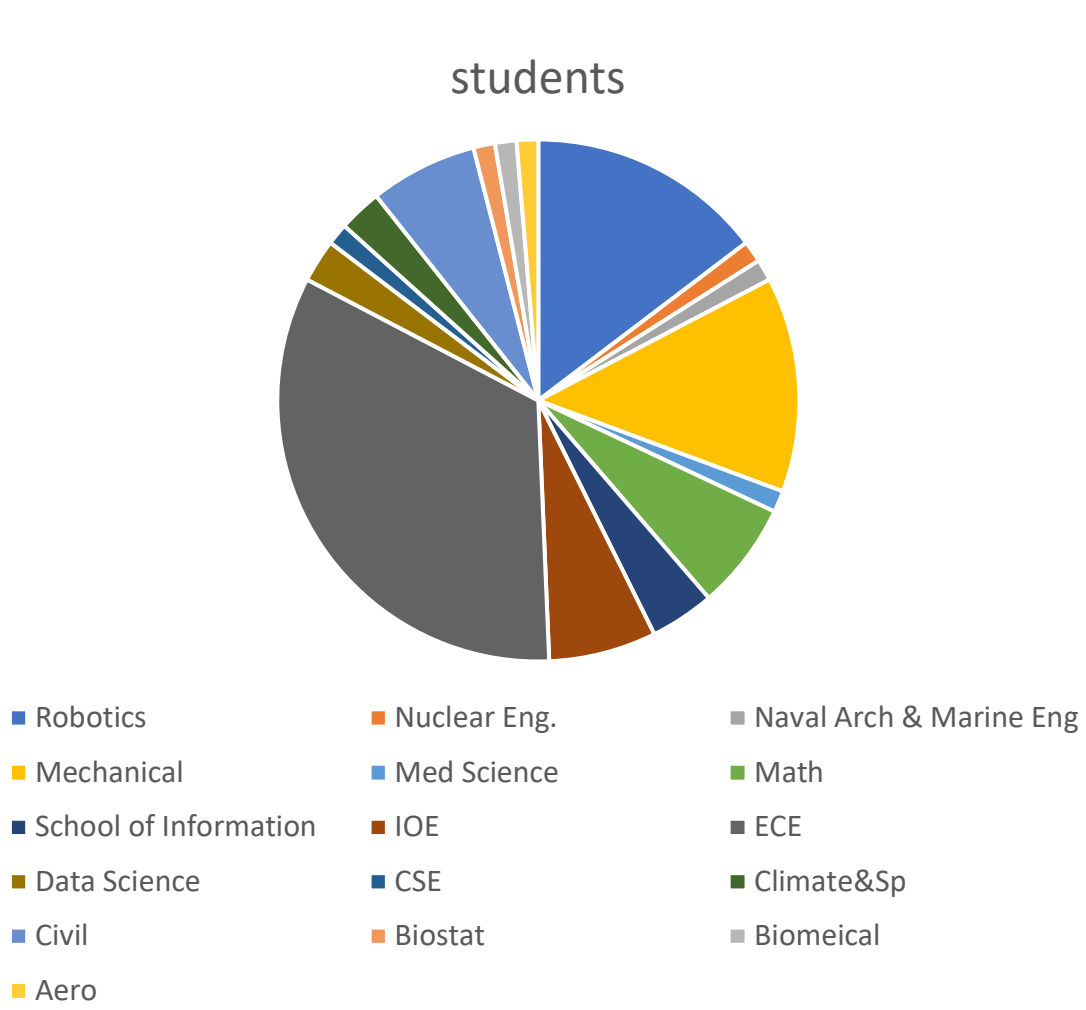
1. Team: Each team should include 6 to 8 students **from at least two different departments/programs.** Students form their teams, but the instructor reserves the right to reorganize and finalize the project teams. (Please email the GSIs if you want to be assigned to a team instead of forming your own team.)
2. Final report: 10-page report without including the references (11pt, single column, single spaced)
3. The report should focus on one of the following three topics:
    a. **Topic A: New Theory**: prove a new theoretical result for reinforcement learning.
    b. **Topic B: New Algorithm**: develop a new reinforcement learning algorithm for an existing problem, and demonstrate the improvement of the new algorithm over existing algorithms.
    c. **Topic C: New Dataset:** apply existing reinforcement learning algorithms to one or multiple datasets, which have not been studied using reinforcement learning.
4. Please identify the topic (theory, algorithm, or dataset) in the title. The report should clearly summarize the new contributions in the introduction.

Reinforcement Learning

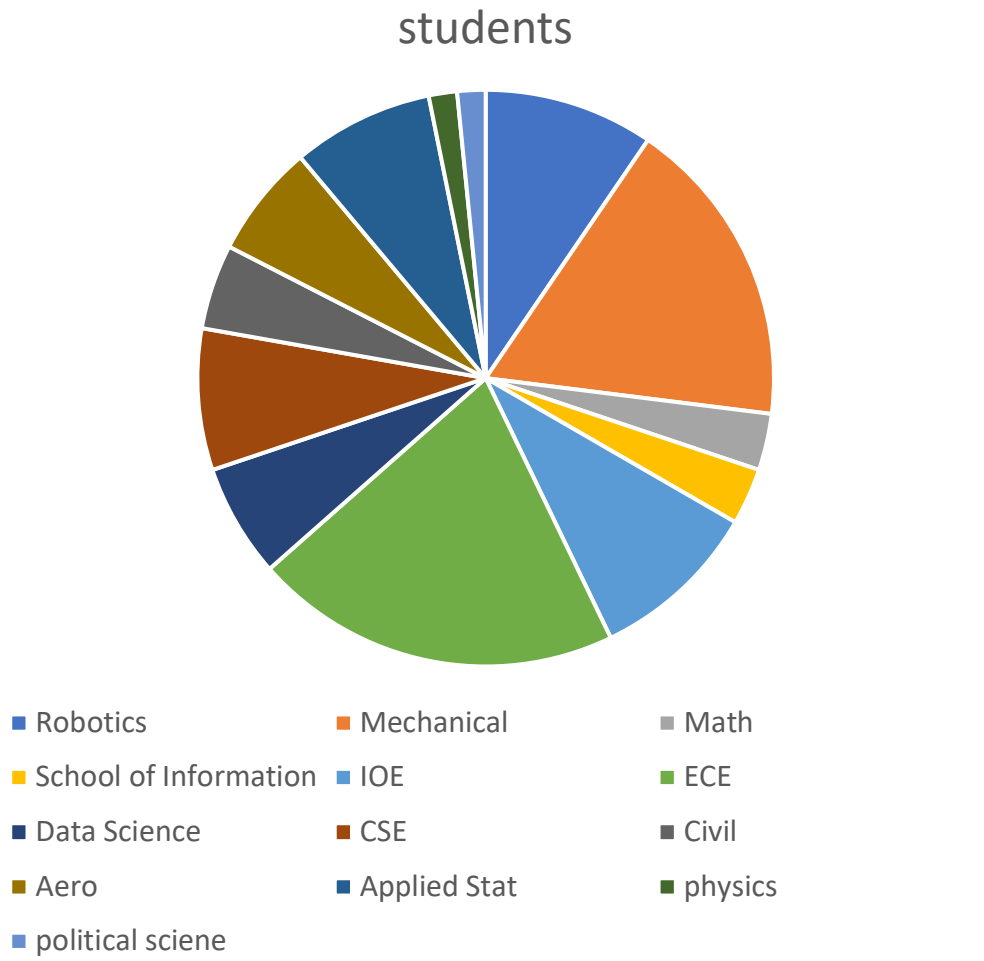
- Prerequisites: EECS 501 (advisory)
- Topics: This course covers fundamental theories and principles of reinforcement learning.
    - Value iteration
    - Policy iteration
    - Q-learning
    - SARSA
    - Policy-gradient Variance reduction
    - Linear and nonlinear function approximation
    - Deep reinforcement learning
    - Exploration-exploitation
    - Convergence analysis
    - Regret analysis

- Motivation: Reinforcement learning has applications in artificial intelligence, machine learning, control, and communication networks. This course complements the existing curriculum in machine learning, stochastic control, and networks.
- FA 2020: Enrollment - 63
  - Evaluation: Q1 (course): 4.6, Q2 (instructor):4.5, Q4 (desire to take course):4.8, Q891 (workload):2.7
- WN 2020: Enrollment - 76
  - Evaluation: Q1:4.00, Q2: 4.10, Q4: 4.50, Q891: 3.2

WN 2020



Fall 2020



Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☐ New Course
- ☐ Modification of Existing Course
- ☑ Deletion of Existing Course

Date of Submission: 2021-11-15
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☐	Dept (Home): Industrial & Operations Engin Subject: IOE Catalog: 635	Dept (Home): Subject: Catalog:
☐	☑ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number Biomedical Engineering - BIOMEDE - 635	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number
☐	Course Title (full title) Laboratory in Biomechanics and Physiology of Work	Course Title (full title)
☐	Abbreviated Title (20 char) Biomec Phys Lab	Abbreviated Title (20 char)
☐	Course Description (Please limit to 50 words and attach separate sheet if necessary) This laboratory is offered in conjunction with the Occupational Biomechanics lecture course (IOE 534) to enable students to examine experimentally (1) musculoskeletal reactions to volitional acts; (2) the use of electromyography (EMGs) to evaluate muscle function and fatigue; (3) biomechanical models; (4) motion analysis system; and (5) musculoskeletal reactions to vibrations.	
☐	Full Term Credit Hours Undergraduate Min: Graduate Min: 2 Undergraduate Max: Graduate Max: 2	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☐	Course Credit Type Rackham Graduate Student, Non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: Industrial & Operations Engin Catalog: 635

☐

Grading Basis
- ☑ Graded (A – E)
- ☐ Credit/No Credit
- ☐ Satisfactory/Unsatisfactory
- ☐ Pass/Fail
- ☐ Business Administration

Grading
- ☐ Not for Credit
- ☐ Not for Degree Credit
- ☐ Degree Credit Only

Add Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

Drop Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

	CURRENT LISTING	**REQUESTED LISTING**
☐	Advisory Prerequisite (254 char) IOE/Biomede 534	Advisory Prerequisite (254 char)
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☐

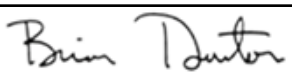
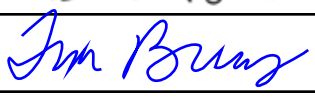
Course Components	Graded Component
☐ Lecture	☐
☐ Seminar	☐
☐ Recitation	☐
☑ Lab	☑
☐ Discussion	☐
☐ Independent Study	☐

Terms Typically Offered
- ☐ Fall
- ☑ Winter
- ☐ Spring
- ☐ Summer
- ☐ Spring/Summer

Cognizant Faculty Member Name: Bernard Martin Cognizant Faculty Member Title: Associate Professor

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Leonora Lucaj Email: lucajl@umich.edu Phone: 734-764-3297

CoE Curriculum Committee Representative:		Print: Yavuz Bozer	Date: 11/16/21
CoE Curriculum Committee Chair:		Print:	Date:
Home Department Chair:		Print: Brian Denton	Date: 11/17/21
Cross-Listed Department Chair:		Print: Tim Bruns	Date: 11/16/21
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description This laboratory is offered in conjunction with the Occupational Biomechanics lecture course (IOE 534) to enable students to examine experimentally (1) musculoskeletal reactions to volitional acts; (2) the use of electromyography (EMGs) to evaluate muscle function and fatigue; (3) biomechanical models; (4) motion analysis system; and (5) musculoskeletal reactions to vibrations.	Course Description
Class Length Full term	Class Length
Contact hours (lecture):	Contact hours (lecture):
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab) 2	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
This course is being deleted so a new version of it can take its place.

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☑ New Course
- ☐ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-11-15
Effective Term: Fall 2022

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☑	Dept (Home): Subject: Catalog:	Dept (Home): Industrial & Operations Engin Subject: IOE Catalog: 635
☐	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number	☐ Course is Cross-Listed with Other Departments Department / Subject / Catalog Number
☑	Course Title (full title)	Course Title (full title) Research Methods Laboratory for Human Subjects
☑	Abbreviated Title (20 char)	Abbreviated Title (20 char) Res Methods Lab
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Knowledge in research methods is acquired to understand human-machine interaction and performance via sensorimotor and cognitive concepts. Through laboratory experiments and research critiques students learn: 1) muscle function, fatigue, vibration response, 2) movement analysis, 3) posture control, 4) controls-displays in complex systems, 5) wearable technologies, 6) tactile perception, 7) psychophysics.	
☑	Full Term Credit Hours Undergraduate Min: Graduate Min: 3 Undergraduate Max: Graduate Max: 3	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☑	Course Credit Type Rackham Graduate Student, Non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject:	Catalog:

☑	Grading Basis ☑ Graded (A – E) ☐ Credit/No Credit ☐ Satisfactory/Unsatisfactory ☐ Pass/Fail ☐ Business Administration Grading ☐ Not for Credit ☐ Not for Degree Credit ☐ Degree Credit Only	Add Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent	Drop Consent ☐ Department Consent ☐ Instructor Consent ☑ No Consent

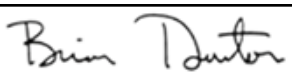
	CURRENT LISTING	**REQUESTED LISTING**
☑	Advisory Prerequisite (254 char)	Advisory Prerequisite (254 char) IOE 534, 533, 536 or other equivalent courses with permission of instructor
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☑	Course Components ☐ Lecture ☐ Seminar ☐ Recitation ☑ Lab ☐ Discussion ☐ Independent Study	Graded Component ☐ ☐ ☐ ☑ ☐ ☐	Terms Typically Offered ☐ Fall ☑ Winter ☐ Spring ☐ Summer ☐ Spring/Summer

Cognizant Faculty Member Name: Bernard Martin	Cognizant Faculty Member Title: Associate Professor

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Leonora Lucaj Email: lucajl@umich.edu Phone: 734-764-3297

CoE Curriculum Committee Representative:		Print: Yavuz Bozer	Date: 11/16/21
CoE Curriculum Committee Chair:		Print:	Date:
Home Department Chair:		Print: Brian Denton	Date: 11/17/21
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:
Cross-Listed Department Chair:		Print:	Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description	Course Description Knowledge in research methods is acquired to understand human-machine interaction and performance via sensorimotor and cognitive concepts. Through laboratory experiments and research critiques students learn: 1) muscle function, fatigue, vibration response, 2) movement analysis, 3) posture control, 4) controls-displays in complex systems, 5) wearable technologies, 6) tactile perception, 7) psychophysics.
Class Length	Class Length Full term
Contact hours (lecture):	Contact hours (lecture):
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab) 3

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:

Special resources of facilities required for this course:

Supporting statement:
This course is being created after the previous version was deleted.

A majority of students have not yet acquired sufficient:
- knowledge of human research methods and the functioning of human systems
- hands-on experience of experimental and research practice
- instrumentation and signal processing
- experience in scientific writing and reading synthesis

Although several courses include various aspects of human performance, these courses cannot cover the major underlying mechanisms and the way in which to explore/exploit/quantify human performance. Hence the course topics/lab complement the understanding of courses including human systems.

This course was developed to:

update former course IOE 635 lab course.

- acquire the necessary hands-on experience and knowledge of methods adapted to the measurement of human performance (physical and cognitive domains)
- Prepare, at the master level, for any type of work/study involving humans and more particularly in the field of Hum Factors and Ergonomics (HFE).
- understand the most common measures in the field and get further in the understanding and utilization of material taught in lectures (e.g. IOE 533,534,536, 537 or any similar course concerned with human performances) .
- prepare to doctoral studies (running experiments, using instruments, developing a research proposal based on experiments and methods, knowledge of method princeps and relevant literature).
- to these ends 4 types of work are included: relevant literature review and critique, formulation of experimental procedures, and discussion of results, laboratory measures, writing of review summary and paper for each “lab experiment”.

Overall several components have been added to the course. They support the change from a 2 credits to a 3 credits course: Literature review, critique discussions and synthesis exercises are new additions. Also topics covering cognitive systems are new in this update. New laboratory experiments have been added to also include wearable technology. Hence, the old version of the course examined experimentally 5 types of issues while the new version includes 7 types of issues.

So far the students have been very positive about the course and learning experience

Note: The syllabus from 2019 is representative of the regular form of the course as the last offering in 2020 was adapted to Covid-19 constraints (labs after March confinement interruption were replaced by other types of work). See schedule for distribution of hours (lectures/discussions - Labs)

David Sept from BME has provided the following statement which supports the deletion of the cross listing: "We simply do not have any faculty that work in this area any more, so if this would be revived, it would need to be done without us. We might have a student or two that was interested in the class, but we have also dropped Ortho/Rehab/Kinesiology as a concentration for our students since there was little interest in the area."

IOE 591:100 ERGONOMICS RESEARCH METHODS LABORATORY

WINTER 2018

Class Time: **Tue, Thu: 10:30am – 12:00pm**
Location: **IOE G699 (classroom) and G707 (lab)**

Instructors: **Profs. Clive D'Souza and Bernard Martin**
Office: **G636 IOE ; G650 IOE**
Email: **crdsouza@umich.edu; martinbj@umich.edu**

Office Hours: **TBD, or by appointment.**

Course Webpage: **https://umich.instructure.com/courses/211180**

Course Description:
This course supports multiple courses in ergonomics/human factors by providing students in-depth knowledge in research methods to understand human-machine interaction and performance. Students will learn through laboratory experiments and research critiques: 1) muscle function, fatigue, vibration response, 2) movement analysis, 3) posture control, 4) controls-displays in complex systems, 5) tactile perception, 6) wearable technologies, and 7) psychophysics.

Course Objectives
This course will be in support of IOE 533, 534, 536, 537, or any similar course concerned with measurement of human performance or human-machine interaction. Seven sets of laboratory experiments each augmented with an in-class component emphasizing journal paper reviews (written critiques and group discussions) will be covered to develop a thorough understanding of the theoretical underpinnings and experimental design issues in ergonomics research methods.

Course Format
The course covers 7 major topic areas (i.e., muscle function, movement, posture control, controls-displays, tactile perception, physiology, and psychophysics) with in-class and lab time each week according to the schedule attached. Each topic area spans 2 weeks amounting to 3 hours in-class time and 3 hours in the laboratory per topic area. Laboratory hours will be conducted in sections of 4 students each, with the number of sections subject to enrollment.

Students meet twice per week, alternating between classroom and lab time each week. The class meets in Room G699 of the IOE building. However the labs are performed at times arranged according to the students' schedules and are generally held in Rooms G707 or G699 of the IOE building.

Readings:
Reading material will be posted on Canvas. These consist of selected journal manuscripts and book chapters, amounting to 2-3 readings per week that will be assigned for critical review and group discussion as part of the in-class time. Readings are selected to cover important theoretical underpinnings and experimental design issues (such as study design, principles and mechanisms of measurement, instrumentation, challenges in data processing and analysis, other advanced instrumentation techniques and their strengths and limitations).

Research Reviews:
Students will be required to submit a written critique for one journal paper per class indicated on Canvas. Students are required to individually prepare and print a formal review (2 pg. max) of readings marked as "Review required" using the template provided. Reviews must be brought to class to facilitate the discussion and submitted to the Instructor at the end of class. 6 of 7 reviews will graded; thus students may choose to skip one review.

Lab Reports
Seven structured laboratory experiments are performed by students operating in groups of 3 or 4. Group reports are due one week after executing each experiment and discussing the results in class. Relevant readings need to be cited in developing the Results and Discussion section of the lab reports.

Grading Scheme:
No exams. The course will be graded on weighted average of the 7 lab reports and 6 of 7 research reviews.

Research Reviews (6 of 7 nos.)	30%
Lab Reports (7 nos.)	70%

Grades:

Grade	Minimum %	Grade	Minimum %
A+	≥ 95*	C+	≥ 73
A	≥ 90	C	≥ 65
A-	≥ 87	C-	≥ 60
B+	≥ 83	D	≥ 55
B	≥ 80	E	≥ 50*
B-	≥ 77	F	< 50*

** You would need to work hard consistently through the term to achieve these grades.*

Class Rules and Policies:

- Students are responsible for reading the material (posted on *Canvas*) for each class beforehand.

- As a graduate class, students are expected to be able to discuss the material in class. It is essential that every student participate in the discussions of course material. This involves being adequately prepared to provide a summary or highlights of the readings for the day, including methods, findings, and design application with examples. Discussions and comments should be professional and respectful, be based on course readings and critical thinking, and should be respectful of differing perspectives.

- If you are unable to attend class or complete work on time due to an illness or family emergency, notify the Instructor at least 1-day before (> 24 hrs.) the critical period with proper documentation explaining the absence, and be prepared to make up work promptly. If unable to attend class then research paper reviews and assignments must be submitted via Canvas before the deadline time.

- Students will be required to present and lead one class discussion during the semester. This involves a short presentation and/or key highlights of the readings for the day, including methods, findings, and design application with examples.

Standards for written work

Research paper reviews must strictly follow the template provided. Research paper reviews must be submitted in-print at the start of class.

Lab reports must be typed and formatted as per specifications provided and submitted electronically on Canvas, either as a docx or pdf file.

Lab reports must have a 1 in. margin, and double-spaced using 12-point Times Roman Font. The cover page should contain the course name, lab number and title, student names (and contribution for lab reports), and date.

Use complete, grammatical sentences. Please pay attention to issues of spelling, grammar, syntax and punctuation. Carelessly written papers that have not been proofread and contain frequent obvious spelling and punctuation errors will be returned without a grade.

Statement on Academic Integrity

All references to other's work, including web pages, must be appropriately cited. Direct quotes must be cited appropriately with quotation marks and page numbers. Do not directly quote without doing this. Do not paraphrase text without citing the source. This includes figures and tables. This must be done to prevent plagiarism, which is both illegal and unethical.

In text, citations and references should adhere to the APA style or the MLA style guide. In text citations must use the authors' last name. DO NOT use authors' first names or the titles of the paper when citing material in the text. For additional help, see "APA Style" or "MLA Style" at http://guides.lib.umich.edu/citationhelp

If you copy or paraphrase material from other sources, including websites, and do not appropriately cite it, it will be treated as an instance of plagiarism and academic dishonesty. This may result in significant grade reduction, and more severe academic consequences with subsequent violations.

If you do not understand how or when to appropriately cite other's work, then you can consult librarians, published style guides, or the Course Instructors.

You MUST follow the Honor Code requirements at all times. See http://www.engin.umich.edu/students/honorcode/code/index.html

University of Michigan Disability Statement:

The University of Michigan is committed to providing equal opportunity for participation in all programs, services and activities. Request for accommodations by persons with disabilities may be made by contacting the Services for Students with Disabilities (SSD) Office located at G 664 Haven Hall. The SSD phone number is 734-763-3000. Once your eligibility for an accommodation has been determined, you will be issued a verified individual services accommodation (VISA) form. Please present this form to the Instructor at the start of the term or at least two weeks prior to the accommodation date such as for a test, project report, etc.

Student Well-being

CoE faculty and staff believe it is important to support the physical and emotional well-being of our students. If you have a physical or mental health issue that is affecting your performance or participation in any course, and/or if you need help connecting with University services, please contact the course instructor or the Office of Academic Affairs.
For more information please see https://ossa.engin.umich.edu/ and https://caps.engin.umich.edu/

Students who expect to miss classes, examinations, or other assignments as a consequence of their religious observance shall be provided with a reasonable alternative opportunity to complete such academic responsibilities. It is the obligation of students to provide faculty with reasonable notice of the dates of religious holidays on which they will be absent.
Please visit http://www.provost.umich.edu/calendar/religious_holidays.html#conflicts for the complete University policy.

IOE 591:100 ERGONOMICS RESEARCH METHODS LABORATORY

WINTER 2018

Course Schedule (- details on Canvas)

Week	Date	Type	Content	Deliverable
1	Jan-4	Classroom	Introduction to course & Module – 1 Readings	
2	Jan-9	Lab	Module – 1 Readings and Presentation of Lab-1: Force and the function of the Musculoskeletal system: strength, fatigue, response to vibration, Electromyography and electrical stimulation	PEERS certification due
	Jan-11	Lab	Lab-1 Exercise	
3	Jan-16	Classroom	Discussion of Lab-1 and Module – 1 Readings	Review 1 due
	Jan-18	Classroom	Module – 2: Readings	Lab 1 report due
4	Jan23	Lab	Presentation of Lab-2: Posture and Force Production: motion capture and analysis methods, force measurement load cells	Review 2 due
	Jan-25	Lab	Lab-2 Exercise	
5	Jan-30	Classroom	Discussion of Lab-2 and Module – 2: Readings	
	Feb-1	Classroom	Module – 3: Readings	Lab 2 report due
6	Feb-6	Lab	Presentation of Lab-3: Balance and Posture Control: effects of muscle vibration on posture control	Review 3 due
	Feb-8	Lab	Lab-3 Exercise	
7	Feb-13	Classroom	Discussion of Lab-3 and Module – 3: Readings	
	Feb-15	Classroom	Module – 4: Readings	Lab 3 report due
8	Feb-20	Lab	Presentation of Lab-4: visual displays and controls in a complex environment	Review 4 due
	Feb-22	Lab	Lab-4 Exercise	
	Feb-27		***Break – no class***	
	Mar-1		***Break – no class***	
9	Mar-6	Classroom	Discussion of Lab-4 and Module – 4: Readings	
	Mar-8	Classroom	Module – 5: Readings	Lab 4 report due
10	Mar-13	Lab	Presentation of Lab-5: Tactile perception and vibrotactile displays	Review 5 due
	Mar-15	Lab	Lab-5 Exercise	
11	Mar-20	Classroom	Discussion of Lab-5 and Module – 5: Readings	
	Mar-22	Classroom	Module – 6: Readings	Lab 5 report due
12	Mar-27	Lab	Presentation of Lab-6. Physiology and Wearable devices	Review 6 due
	Mar-29	Lab	Lab-6 Exercise	
13	Apr-3	Classroom	Discussion of Lab-5 and Module – 6: Readings	
	Apr-5	Classroom	Module – 7: Readings Lab 5 due and disc lab6	
14	Apr-10	Lab	Presentation of Lab-7: Methods in psychophysics, ratings vs rankings Lab 6 due	Review 7 due
	Apr-12	Classroom	Discussion of Lab-7 Lab 7 TBD 12 or 13 evening	
15	Apr-17	Classroom	Semester Review	Lab 7 report due

Last Updated: January 2, 2018

IOE 591:100 W19 ERGONOMICS RESEARCH METHODS LABORATORY

Class Time: Tue, Thu: 9:00am – 10:30pm
Location: IOE G699 (classroom) and G707 (lab)

Instructors: Prof. Bernard Martin and Ms. Sol Lim
Office: G650 IOE; G831 IOE
Email: martinbj@umich.edu; solielim@umich.edu

Office Hours: TBD, or by appointment.

Course Webpage: https://umich.instructure.com/courses/270345

Course Description:
This course supports multiple courses in ergonomics/human factors (and any course including human systems) by providing students in-depth knowledge in research methods to understand human-machine interaction and performance. Students will learn through laboratory experiments and research critiques: 1) muscle function, fatigue, vibration response, 2) movement analysis, 3) posture control, 4) controls-displays in complex systems, 5) wearable technologies, 6) tactile perception, and 7) psychophysics.

Course Objectives
This course will be in support of IOE 533, 534, 536, 537, or any similar course concerned with measurement of human performance or human-machine interaction. Seven sets of laboratory experiments each augmented with an in-class component emphasizing journal paper reviews (written critiques and group discussions) will be covered to develop a thorough understanding of the theoretical underpinnings and experimental design issues in ergonomics research methods.

Course Format
The course covers 7 major topic areas (i.e., muscle function, movement, posture control, controls-displays, physiology, tactile perception, and psychophysics) with in-class and lab time each week according to the schedule attached. Each topic area spans 2 weeks amounting to 3 hours in-class time and 3 hours in the laboratory per topic area. Laboratory hours will be conducted in sections of 4 students each, with the number of sections subject to enrollment.

Students meet twice per week, alternating between classroom and lab time each week. The class meets in Room G699 of the IOE building. However the labs are performed at times arranged according to the students' schedules and are generally held in Rooms G707 or G699 of the IOE building.

Readings:
Reading material will be posted on Canvas. These consist of selected journal manuscripts and book chapters, amounting to 2-3 readings per week that will be assigned for critical review and group discussion as part of the in-class time. Readings are selected to cover important theoretical underpinnings and experimental design issues (such as study design, principles and mechanisms of measurement, instrumentation, challenges in data processing and analysis, other advanced instrumentation techniques and their strengths and limitations).

Research Reviews:

Students will be required to submit a written critique for one journal paper per class indicated on Canvas. Students are required to individually prepare and print a formal review (2 pg. max) of readings marked as "Review required" using the template provided. Reviews must be brought to class to facilitate the discussion and submitted to the Instructor at the end of class. 6 of 7 reviews will graded; thus students may choose to skip one review.

Lab Reports

Seven structured laboratory experiments are performed by students operating in groups of 3 or 4. Group reports are due one week after executing each experiment and discussing the results in class. Relevant readings need to be cited in developing the Results and Discussion section of the lab reports.

Grading Scheme:

No exams. The course will be graded on weighted average of the 7 lab reports and 6 of 7 research reviews.

Research Reviews (6 of 7 nos.)	30%
Lab Reports (7 nos.)	70%

Grades:

Grade	Minimum %	Grade	Minimum %
A+	≥ 95*	C+	≥ 73
A	≥ 90	C	≥ 65
A-	≥ 87	C-	≥ 60
B+	≥ 83	D	≥ 55
B	≥ 80	E	≥ 50*
B-	≥ 77	F	< 50*

** You would need to work hard consistently through the term to achieve these grades.*

Class Rules and Policies:

- Students are responsible for reading the material (posted on *Canvas*) for each class beforehand.

- As a graduate class, students are expected to be able to discuss the material in class. It is essential that every student participate in the discussions of course material. This involves being adequately prepared to provide a summary or highlights of the readings for the day, including methods, findings, and design application with examples. Discussions and comments should be professional and respectful, be based on course readings and critical thinking, and should be respectful of differing perspectives.

- If you are unable to attend class or complete work on time due to an illness or family emergency, notify the Instructor at least 1-day before (> 24 hrs.) the critical period with proper documentation explaining the absence, and be prepared to make up work promptly. If unable to attend class then research paper reviews and assignments must be submitted via Canvas before the deadline time.

- Students will be required to present and lead one class discussion during the semester. This involves a short presentation and/or key highlights of the readings for the day, including methods, findings, and design application with examples.

Standards for written work

Research paper reviews must strictly follow the template provided. Research paper reviews must be submitted in-print at the start of class.

Lab reports must be typed and formatted as per specifications provided and submitted electronically on Canvas, either as a docx or pdf file.

Lab reports must have a 1 in. margin, and double-spaced using 12-point Times Roman Font. The cover page should contain the course name, lab number and title, student names (and contribution for lab reports), and date.

Use complete, grammatical sentences. Please pay attention to issues of spelling, grammar, syntax and punctuation. Carelessly written papers that have not been proofread and contain frequent obvious spelling and punctuation errors will be returned without a grade.

Statement on Academic Integrity

All references to other's work, including web pages, must be appropriately cited. Direct quotes must be cited appropriately with quotation marks and page numbers. Do not directly quote without doing this. Do not paraphrase text without citing the source. This includes figures and tables. This must be done to prevent plagiarism, which is both illegal and unethical.

In text, citations and references should adhere to the APA style or the MLA style guide. In text citations must use the authors' last name. DO NOT use authors' first names or the titles of the paper when citing material in the text. For additional help, see "APA Style" or "MLA Style" at http://guides.lib.umich.edu/citationhelp

If you copy or paraphrase material from other sources, including websites, and do not appropriately cite it, it will be treated as an instance of plagiarism and academic dishonesty. This may result in significant grade reduction, and more severe academic consequences with subsequent violations.

If you do not understand how or when to appropriately cite other's work, then you can consult librarians, published style guides, or the Course Instructors.

You MUST follow the Honor Code requirements at all times. See http://www.engin.umich.edu/students/honorcode/code/index.html

University of Michigan Disability Statement:

The University of Michigan is committed to providing equal opportunity for participation in all programs, services and activities. Request for accommodations by persons with disabilities may be made by contacting the Services for Students with Disabilities (SSD) Office located at G 664 Haven Hall. The SSD phone number is 734-763-3000. Once your eligibility for an accommodation has been determined, you will be issued a verified individual services accommodation (VISA) form. Please present this form to the Instructor at the start of the term or at least two weeks prior to the accommodation date such as for a test, project report, etc.

Student Well-being

CoE faculty and staff believe it is important to support the physical and emotional well-being of our students. If you have a physical or mental health issue that is affecting your performance or participation in any course, and/or if you need help connecting with University services, please contact the course instructor or the Office of Academic Affairs.
For more information please see https://ossa.engin.umich.edu/ and https://caps.engin.umich.edu/

Students who expect to miss classes, examinations, or other assignments as a consequence of their religious observance shall be provided with a reasonable alternative opportunity to complete such academic responsibilities. It is the obligation of students to provide faculty with reasonable notice of the dates of religious holidays on which they will be absent.
Please visit http://www.provost.umich.edu/calendar/religious_holidays.html#conflicts for the complete University policy.

IOE 591:100 W19 ERGONOMICS RESEARCH METHODS LABORATORY

Course Schedule (- details on Canvas)

General Lab time for **G1: M 2-5 pm**
G2: W 1-4 pm **These times may be adjusted for some labs**

Week	Date	Type	Content	Deliverable
1	Jan-10	Classroom	Introduction to course & Module – 1 Readings	
2	Jan-15	Lab	Module – 1 Readings and Presentation of Lab-1: Force and the function of the Musculoskeletal system: strength, fatigue, response to vibration, and Electromyography	PEERS certification due
	Jan-17	Lab	Lab-1 Exercise	
3	Jan-22	Classroom	Discussion of Lab-1 and Module – 1: Readings	Review 1 due
	Jan-24	Classroom	Module – 2: Readings Presentation of Lab-2: : Balance and Posture Control: effects of muscle vibration on posture control	Lab 1 report due
4	Jan-29	Lab	Lab 2 Exercise **G1**	Review 2 due
	Feb- 1	Lab	Lab-2 Exercise **G2**	
5	Feb-5	Classroom	Discussion of Lab-2 and Module – 2: Readings	
	Feb-7	Classroom	Module – 3: Readings Presentation of Lab-3: Posture and Force Production: motion capture and analysis methods, force measurement load cells	Lab 2 report due
6	Feb-12	Lab	Lab-3 Exercise **G1** **(IF POSSIBLE IT HELPS)**	Review 3 due
	Feb-13	Lab	Lab-3 Exercise **G2**	
7	Feb-19	Classroom	Discussion of Lab-3 and Module – 3: Readings (**Sol Lim**)	
	Feb-21	Classroom	Module – 4: Readings (Clive)	Lab 3 report due
8	Feb-26	Lab	Presentation of Lab-4: visual displays and controls in a complex environment	Review 4 due
	Feb-27 Mar-11	Lab	Lab-4 Exercise **G2** Lab-4 Exercise **G1**	
	Mar-5		***Break – no class***	
	Mar-7		***Break – no class***	
9	Mar-14	Classroom	Discussion of Lab-4 and Module – 4: Readings	
	Mar-19	Classroom	Module – 5: Readings	Lab 4 report due
10	Mar-21	Lab	Presentation of Lab-5. Tactile perception and vibrotactile displays	Review 5 due
	Mar-27 Apr- 1	Lab	Lab-5 Exercise **G2** Lab-5 Exercise **G1**	
11	Mar-28	Classroom	Discussion of Lab-5 and Module – 5: Readings	
	Apr-2	Classroom	Module – 6: Readings	Lab 5 report due
12	Apr-4	Lab	Presentation of Lab-6: Physiology and Wearable devices	Review 6 due
	Apr-8 Apr-15	Lab	Lab-5 Exercise **G2** Lab-5 Exercise **G1**	
13	Apr-11	Classroom	Discussion of Lab-6 and Module – 6: Readings	
	Apr-16	Classroom	Module – 7: Readings	Lab 6 report due
14	Apr-18 Apr-19	Lab	Presentation of Lab-7: Methods in psychophysics, ratings vs rankings **Lab 7**	Review 7 due
	Apr-23	Classroom	Discussion of Lab-7 and Semester Review	

15	Apr-25	No Class		Lab 7 report due

IOE 591:100 W20 ERGONOMICS +ANY RESEARCH METHODS LABORATORY

Proposed/Revised Syllabus for change from 2 credits to 3 credits

Class Time: **Tue, Thu: 9:00am – 10:30pm**
Location: **IOE G699 (classroom) and G707 (lab)**

Instructors: **Prof. Bernard Martin**
Office: **G650 IOE; G831 IOE**
Email: **martinbj@umich.edu**

Office Hours: **TBD, or by appointment.**

Course Webpage:

Course Description:
This course supports multiple courses in ergonomics/human factors (and any course including human systems) by providing students in-depth knowledge in research methods to understand human-machine interaction and performance. Students will learn through laboratory experiments and research critiques: 1) muscle function, fatigue, vibration response, 2) movement analysis, 3) posture control, 4) controls-displays in complex systems, 5) wearable technologies, 6) tactile perception, and 7) psychophysics.

Course Objectives
This course will be in support of IOE 533, 534, 536, 537, or any similar course concerned with measurement of human performance or human-machine interaction. Seven sets of laboratory experiments each augmented with an in-class component emphasizing journal paper reviews (written critiques and group discussions) will be covered to develop a thorough understanding of the theoretical underpinnings and experimental design issues in ergonomics research methods.

Course Format
The course covers 7 major topic areas (i.e., muscle function, movement, posture control, controls-displays, physiology, tactile perception, and psychophysics) with in-class and lab time each week according to the schedule attached. Each topic area spans 2 weeks amounting to 3 hours in-class time and 3 hours in the laboratory per topic area. Laboratory hours will be conducted in sections of 4 students each, with the number of sections subject to enrollment.

Students meet twice per week, alternating between classroom and lab time each week. The class meets in Room G699 of the IOE building. However the labs are performed at times arranged according to the students' schedules and are generally held in Rooms G707 or G699 of the IOE building.

Readings:
Reading material will be posted on Canvas. These consist of selected journal manuscripts and book chapters, amounting to 2-3 readings per week that will be assigned for critical review and group discussion as part of the in-class time. Readings are selected to cover important theoretical underpinnings and experimental design issues (such as study design, principles and mechanisms of measurement, instrumentation, challenges in data processing and analysis, other advanced instrumentation techniques and their strengths and limitations).

Research Reviews:
Students will be required to submit a written critique for one journal paper per class indicated on Canvas. Students are required to individually prepare and print a formal review (2 pg. max) of readings marked as "Review required" using the template provided. Reviews must be brought to class to facilitate the discussion and submitted to the Instructor at the end of class. 6 of 7 reviews will graded; thus students may choose to skip one review.

Lab Reports
Seven structured laboratory experiments are performed by students operating in groups of 3 or 4. Group reports are due one week after executing each experiment and discussing the results in class. Relevant readings need to be cited in developing the Results and Discussion section of the lab reports.

Grading Scheme:
No exams. The course will be graded on weighted average of the 7 lab reports and 6 of 7 research reviews.

Research Reviews (6 of 7 nos.)	30%
Lab Reports (7 nos.)	70%

Grades:

Grade	Minimum %	Grade	Minimum %
A+	≥ 95*	C+	≥ 73
A	≥ 90	C	≥ 65
A-	≥ 87	C-	≥ 60
B+	≥ 83	D	≥ 55
B	≥ 80	E	≥ 50*
B-	≥ 77	F	< 50*

* *You would need to work hard consistently through the term to achieve these grades.*

Class Rules and Policies:

- Students are responsible for reading the material (posted on *Canvas*) for each class beforehand.

- As a graduate class, students are expected to be able to discuss the material in class. It is essential that every student participate in the discussions of course material. This involves being adequately prepared to provide a summary or highlights of the readings for the day, including methods, findings, and design application with examples. Discussions and comments should be professional and respectful, be based on course readings and critical thinking, and should be respectful of differing perspectives.

- If you are unable to attend class or complete work on time due to an illness or family emergency, notify the Instructor at least 1-day before (> 24 hrs.) the critical period with proper documentation explaining the absence, and be prepared to make up work promptly. If unable to attend class then research paper reviews and assignments must be submitted via Canvas before the deadline time.

- Students will be required to present and lead one class discussion during the semester. This involves a short presentation and/or key highlights of the readings for the day, including methods, findings, and design application with examples.

Standards for written work

Research paper reviews must strictly follow the template provided. Research paper reviews must be submitted in-print at the start of class.

Lab reports must be typed and formatted as per specifications provided and submitted electronically on Canvas, either as a docx or pdf file.

Lab reports must have a 1 in. margin, and double-spaced using 12-point Times Roman Font. The cover page should contain the course name, lab number and title, student names (and contribution for lab reports), and date.

Use complete, grammatical sentences. Please pay attention to issues of spelling, grammar, syntax and punctuation. Carelessly written papers that have not been proofread and contain frequent obvious spelling and punctuation errors will be returned without a grade.

Statement on Academic Integrity

All references to other's work, including web pages, must be appropriately cited. Direct quotes must be cited appropriately with quotation marks and page numbers. Do not directly quote without doing this. Do not paraphrase text without citing the source. This includes figures and tables. This must be done to prevent plagiarism, which is both illegal and unethical.

In text, citations and references should adhere to the APA style or the MLA style guide. In text citations must use the authors' last name. DO NOT use authors' first names or the titles of the paper when citing material in the text. For additional help, see "APA Style" or "MLA Style" at http://guides.lib.umich.edu/citationhelp

If you copy or paraphrase material from other sources, including websites, and do not appropriately cite it, it will be treated as an instance of plagiarism and academic dishonesty. This may result in significant grade reduction, and more severe academic consequences with subsequent violations.

If you do not understand how or when to appropriately cite other's work, then you can consult librarians, published style guides, or the Course Instructors.

You MUST follow the Honor Code requirements at all times. See http://www.engin.umich.edu/students/honorcode/code/index.html

University of Michigan Disability Statement:

The University of Michigan is committed to providing equal opportunity for participation in all programs, services and activities. Request for accommodations by persons with disabilities may be made by contacting the Services for Students with Disabilities (SSD) Office located at G 664 Haven Hall. The SSD phone number is 734-763-3000. Once your eligibility for an accommodation has been determined, you will be issued a verified individual services accommodation (VISA) form. Please present this form to the Instructor at the start of the term or at least two weeks prior to the accommodation date such as for a test, project report, etc.

Student Well-being

CoE faculty and staff believe it is important to support the physical and emotional well-being of our students. If you have a physical or mental health issue that is affecting your performance or participation in any course, and/or if you need help connecting with University services, please contact the course instructor or the Office of Academic Affairs.
For more information please see https://ossa.engin.umich.edu/ and https://caps.engin.umich.edu/

Students who expect to miss classes, examinations, or other assignments as a consequence of their religious observance shall be provided with a reasonable alternative opportunity to complete such academic responsibilities. It is the obligation of students to provide faculty with reasonable notice of the dates of religious holidays on which they will be absent.
Please visit http://www.provost.umich.edu/calendar/religious_holidays.html#conflicts for the complete University policy.

IOE 591:100 W20 ERGONOMICS +ANY RESEARCH METHODS LABORATORY

Course Schedule (- details on Canvas)

General Lab time for G1: M 2-5 pm
G2: W 1-4 pm **These times will be adjusted**

Week	Date	Type	Content	Deliverable
1	Jan-9	Classroom	Introduction to course & Module – 1 Readings	
2	Jan-14	Lab	Module – 1 Readings and Presentation of Lab-1: Force and the function of the Musculoskeletal system: strength, fatigue, response to vibration, and Electromyography	PEERS certification due
	Jan-16	Classroom	Lab-1 Preparation	
3	Jan-21 Jan 22	LAB	Lab 1 Exercise and Discussion G1 2 pm (Natalie, Chenxi, Vibha) G2 1 pm (Patrik, Alexandra, Nick)	Review 1 due
4	Jan-28	Lab	Lab 2 Exercise **G1**	
	Jan-29	Lab	Lab-2 Exercise **G2**	Lab 1 report due
	Feb 4	Classroom	Module – 2: Readings On Position, movement effort	
5	Feb-6	Classroom	Discussion of Lab-2 and Module – 2: Readings	Review 2 due
	Feb-11	Classroom	Module – 3: Readings Presentation of Lab-3: Posture control	Lab 2 report due
6	Feb-11	Lab	Lab-3 Exercise **G1 (IF POSSIBLE IT HELPS)**	Review 3 due
	Feb-13	Lab	Lab-3 Exercise **G2**	
7	Feb-18	Classroom	Discussion of Lab-3 and Module – 3: Readings	
	Feb-20	Classroom	Module – 4: Readings	Lab 3 report due
8	Feb-25	Lab	Presentation of Lab-4: visual displays and controls in a complex environment	Review 4 due
	Feb-27 Mar-10	Lab	Lab-4 Exercise **G2** Lab-4 Exercise **G1**	
	Mar-3		***Break – no class***	
	Mar-5		***Break – no class***	
9	Mar-10	Classroom	Discussion of Lab-4 and Module – 4: Readings	
	Mar-12	Classroom	Module – 5: Readings	Lab 4 report due
10	Mar-17	Lab	Presentation of Lab-5. Tactile perception and vibrotactile displays	Review 5 due
	Mar-19 Mar-24	Lab	Lab-5 Exercise **G2** Lab-5 Exercise **G1**	
11	Mar-26	Classroom	Discussion of Lab-5 and Module – 5: Readings	
	Mar-31	Classroom	Module – 6: Readings	Lab 5 report due
12	Apr-2	Lab	Presentation of Lab-6: Physiology and Wearable devices	Review 6 due
	Apr-7 Apr-9	Lab	Lab-5 Exercise **G2** Lab-5 Exercise **G1**	
13	Apr-14	Classroom	Discussion of Lab-6 and Module – 6: Readings	
	Apr-16	Classroom	Module – 7: Readings	Lab 6 report due
14	Apr-21 Apr-23	Lab	Presentation of Lab-7: Methods in psychophysics, ratings vs rankings **Lab 7**	Review 7 due
	Apr-23	Classroom	Discussion of Lab-7 and Semester Review	Lab 7 report due

Course Approval Request Form

Office of the Registrar, University of Michigan

1210 LSA Building
500 S. State Street
Ann Arbor, MI 48109-1382
Phone: 734.763.2113
Fax: 734.936.3148
ro.curriculum@umich.edu
ro.umich.edu

☑ **CHECK APPROPRIATE BOXES FOR ALL CHANGES**

Action Requested
- ☐ New Course
- ☑ Modification of Existing Course
- ☐ Deletion of Existing Course

Date of Submission: 2021-11-09
Effective Term: Winter 2023

☑	Course Offered ☑ Indefinitely ☐ One term only	**RO USE ONLY** Date Received: Date Completed: Completed By:

	CURRENT LISTING	**REQUESTED LISTING**
☐	Dept (Home): Nuclear Engin & Radiolog Sci Subject: NERS Catalog: 544	Dept (Home): Nuclear Engin & Radiolog Sci Subject: NERS Catalog: 544
☐	☐ Course is Cross-Listed with Other Departments	☐ Course is Cross-Listed with Other Departments
	Department / Subject / Catalog Number	Department / Subject / Catalog Number
☐		
☐	Course Title (full title) Monte Carlo Methods	Course Title (full title) Monte Carlo Methods
☐	Abbreviated Title (20 char) Monte Carlo Meth	Abbreviated Title (20 char) Monte Carlo Meth
☑	Course Description (Please limit to 50 words and attach separate sheet if necessary) Monte Carlo methods applicable to a broad range of scientific disciplines. Topics include probability and statistics, generation of random variates, discrete and continuous Markov chains, random processes, Markov Chain Monte Carlo, simulated annealing, estimation techniques, variance reduction, perturbation methods, Green's functions, and diffusion processes. Applications to particle transport will be covered.	
☑	Full Term Credit Hours Undergraduate Min: Graduate Min: 3 Undergraduate Max: Graduate Max: 3	Half Term Credit Hours Undergraduate Min: Graduate Min: Undergraduate Max: Graduate Max:
☒	Course Credit Type Rackham Graduate Student, non-Rackham Graduate Student	
☐	Repeatability ☐ Course is Repeatable for Credit Maximum number of repeatable credits:	☐ Course is Y graded ☐ Can be taken more than once in the same term

Subject: Nuclear Engin & Radiolog Sci Catalog: 544

☐

Grading Basis
- ☑ Graded (A – E)
- ☐ Credit/No Credit
- ☐ Satisfactory/Unsatisfactory
- ☐ Pass/Fail
- ☐ Business Administration

Grading
- ☐ Not for Credit
- ☐ Not for Degree Credit
- ☐ Degree Credit Only

Add Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

Drop Consent
- ☐ Department Consent
- ☐ Instructor Consent
- ☑ No Consent

	CURRENT LISTING	REQUESTED LISTING
☑	Advisory Prerequisite (254 char) Graduate standing in Engr Math or sciences.	Advisory Prerequisite (254 char) Graduate standing in Engr, Math, or sciences.
☐	Enforced Prerequisite (254 char) Minimum grade requirement:	Enforced Prerequisite (254 char) Minimum grade requirement:
☐	Credit Exclusions	Credit Exclusions

☐

Course Components
- ☑ Lecture
- ☐ Seminar
- ☐ Recitation
- ☐ Lab
- ☐ Discussion
- ☐ Independent Study

Graded Component
- ☑
- ☐
- ☐
- ☐
- ☐
- ☐

Terms Typically Offered
- ☐ Fall
- ☑ Winter
- ☐ Spring
- ☐ Summer
- ☐ Spring/Summer

Cognizant Faculty Member Name: Brian Kiedrowski Cognizant Faculty Member Title: Assoc. Professor

SIGNATURES ARE REQUIRED FROM ALL DEPARTMENTS INVOLVED (Please Print AND Sign Name)

Contact Person: Michelle Sonderman Email: mlwhit@umich.edu Phone: 734-936-3130

CoE Curriculum Committee Representative: Won Sik Yang Print: Won Sik Yang Date: 11/15/2021

CoE Curriculum Committee Chair: Print: Date:

Home Department Chair: [signature] Print: Todd R Allen Date: 15 Nov 2021

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

Cross-Listed Department Chair: Print: Date:

DEPARTMENTAL/COLLEGE USE ONLY

Current:	Requested:
Course Description This course is an introduction to Monte Carlo methods, including basic probability and statistics, random number generation, sampling, scoring and tallies, error estimation, variance reduction, and importance sampling. Examples are drawn from Monte Carlo particle transport. Homework assignments include programming.	Course Description Monte Carlo methods applicable to a broad range of scientific disciplines. Topics include probability and statistics, generation of random variates, discrete and continuous Markov chains, random processes, Markov Chain Monte Carlo, simulated annealing, estimation techniques, variance reduction, perturbation methods, Green's functions, and diffusion processes. Applications to particle transport will be covered.
Class Length Full term	Class Length Full term
Contact hours (lecture): 2	Contact hours (lecture): 3
Contact hours (recitation)	Contact hours (recitation)
Contact hours (lab)	Contact hours (lab)

Additional Info:

Submitted by:
Home dept

Describe how this course fits with the degree requirements:
Elective for graduate programs.

Special resources of facilities required for this course:

Supporting statement:
NERS 544 was first introduced as a special topics course by Prof. William Martin in 1991 designed to attract a broad interest across numerous disciplines. Over the last 30 years, the base of knowledge that a graduate student wishing to understand Monte Carlo methods has grown to the point where covering all the material at a suitable level of depth and rigor for a graduate course is impractical with only 2 credits. Additionally, a poll was conducted of the students during the previous offering in Winter 2021, and there was wide agreement that given the workload, this course should be 3 credits.