ISE GRADUATE MANUAL

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THE ISE GRADUATE PROGRAM

Introduction

The Grado Department of Industrial and Systems Engineering (ISE) offers a broad-based program allowing students to pursue graduate study commensurate with their career goals. Specific strengths of the program are in the areas of human factors engineering and ergonomics, general industrial engineering, management systems engineering, manufacturing systems engineering, operations research, engineering administration, and systems engineering. The Ph.D. degree is offered in Industrial and Systems Engineering, and the master's is offered in Industrial and Systems Engineering (M.S.), Engineering Administration (M.E.A.), and Systems Engineering (M.S.).

The administrative staff of the academic programs of the ISE Department includes:

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Purpose of the Graduate Manual
This graduate manual provides requirements, policies, and procedures adopted by the faculty for current graduate students in industrial and systems engineering (ISE) for successful completion of graduate degrees. Students should be aware that the requirements provided here represent **minimum** requirements for ISE—it is imperative that you consult your advisor before taking classes since the ultimate approval for your course selection rests with the faculty. Additional information concerning graduate school requirements may be found in the Graduate Policies and Procedures and Course Catalog from Virginia Tech.

http://graduateschool.vt.edu/graduate_catalog/

If there is any doubt regarding the interpretation of any regulation or requirement in this manual, or if there are questions about the graduate program involving matters not covered in this manual, please consult the ISE Graduate Program Director, Dr. Maury A. Nussbaum, or the ISE Graduate Program Coordinator, Hannah Parks. **It is each individual student's responsibility to be familiar with all university policies, procedures, and requirements**.

The provisions of this manual do not constitute a contract, expressed or implied, between any applicant or student and the ISE Department or Virginia Polytechnic Institute and State University. The university and the ISE Department reserve the right to change any of the provisions, schedules, programs, courses, rules, regulations, or fees whenever university or departmental authorities deem it expedient to do so.

Administration of ISE Graduate Program
The graduate program is administered by the Graduate Policy Committee (GPC), which is also charged with the responsibility for resolving conflicts that may arise regarding policy or procedural issues. The director of the ISE graduate program chairs the GPC. In addition to chairing the GPC, the director of the graduate program is responsible for implementation of requirements, policies, and procedures adopted by the ISE faculty. The director of the graduate program and members of the GPC are appointed by the ISE department head. The ISE Graduate Admissions Committee (GAC) makes all admission decisions. The GAC also assigns incoming graduate students to a temporary advisor in their primary interest area.

The graduate program coordinator serves as the assistant to the director of the graduate program, maintains the graduate program, is the source of information on the graduate program including but not limited to forms for carrying out graduate program and Graduate School requirements, course registration, grade changes, and other procedures relating to the graduate program.
The current administrative staff for the ISE graduate program includes the following:

Director of the Graduate Program and Chair of the Graduate Policy Committee – Maury A.
    Nussbaum – nussbaum@vt.edu
Graduate Program Coordinator – Hannah Parks – hsswiger@vt.edu
Academic Advisor for Off-Campus Graduate Programs – Paula Van Curen – pcuren@vt.edu
Financial Assistance
The ISE Department has limited financial assistance available for qualified graduate students in the form of graduate teaching assistantships (GTA) and graduate research assistantships (GRA).

Grado, Pratt, NIOSH, Davenport, and Cunningham Fellowships are also available through the ISE department, college of engineering and the Graduate School. The monthly stipend for GTAs and GRAs varies depending on the nature of the assistantship and the graduate level of the student. All assistantships carry a waiver of tuition, except those awarded during summer terms. The student is responsible for comprehensive and other fees (visit http://www.bursar.vt.edu for current fees).

All financial assistance is awarded on a competitive basis, with awards being made to the most qualified students based on merit. GTAs are awarded by the GPC and specific course assignments are made by departmental administration based on teaching needs. A student who is awarded a full-time GTA is obligated for 20 hours of work per week throughout the semester for which the award applies. Typically, a GTA is assigned to a member of the ISE faculty to assist in teaching a course. GRA awards are made to support research projects that are supervised by ISE faculty. Hence, the principal investigator for the research project from which the funding comes awards the GRA. A student receiving a GRA is expected to work 20 hours per week during the semester for which the award applies, the duties being assigned by the principal investigator. In a similar manner, the duties of a student on a fellowship depend on the particular fellowship and are not covered in this manual.

Students holding a full GTA or GRA must carry a course load of at least 12 credit hours per semester, and not more than 18 hours. Students holding less than full GTAs or GRAs receive a proportionally smaller stipend and reduced tuition waiver and carry a proportionally lower workload. However, all students on assistantship must be registered for a minimum of 12 hours per semester.

Graduate Research Assistant (GRA). Graduate research assistants are graduate students conducting academically significant research under the direction of a regular faculty member, who is generally a principal investigator on an external grant or contract.

Graduate Teaching Assistant (GTA). Graduate teaching assistants may assist faculty in teaching lower division courses, including laboratory teaching assignments, or in providing other appropriate professional assistance. First year GTAs with no prior teaching experience will not be assigned full responsibility for lecture courses. In ISE, it is unusual for a GTA to be assigned full course responsibility.

Awarding of Graduate Teaching Assistantships
GTA support depends on the number of positions available and the number of applications for these positions. Graduate student applications for GTA support are invited prior to the start of each academic year. The ISE Graduate Policy Committee reviews these applications and awards GTAs based on the following criteria: a) degree program (Ph.D. students have higher priority than M.S. students); b) academic performance, progress (through program milestones), and productivity (e.g., journal and conference papers); and c) performance of prior GTA duties (if applicable). Ph.D. students who have had GTA support for eight or more academic-year semesters, or have been in the doctoral program for five or more years, will have a reduced priority for support.

Changing From a GTA to GRA

A student may give up a GTA in favor of a GRA up to one month (30 days) before the start of semester classes. Beyond that point in time a GTA may be vacated in favor of a GRA only with the consent of the instructor of the course to which the GTA is assigned and the department head. In the event of a GTA to GRA change, the instructor of the course will work with the GPC to determine the replacement.

Academic Eligibility

A student must maintain a cumulative grade point average of 3.0 or better for all courses taken while in graduate school at Virginia Tech and for all courses transferred for graduate credit at Virginia Tech. At the end of each semester the GPC reviews the progress of each ISE graduate student. Any student with a cumulative grade point average below 3.0 for their last semester of graduate work will be placed on academic probation and may be required to appear before this committee. The purpose of this appearance is to discover the source of the difficulties evidenced by unsatisfactory progress and to outline avenues that the student should pursue to improve their performance. In accordance with Graduate School and ISE departmental policy, any student who fails to meet these requirements in two successive semesters will typically be dismissed from the ISE graduate program.

Graduate Honor System

Academic integrity is essential for maintaining the quality of scholarship in the department and for protecting those who depend on the results of research work performed by faculty and students in the department. The faculty of the Grado Department of Industrial and Systems Engineering expects all students to maintain academic integrity at all times in the classroom and the research laboratory and to conduct their academic work in accordance with the high ethical standards of the engineering profession. Students are expected to maintain academic integrity by refraining from academic dishonesty, and conduct that aids others in academic dishonesty or that leads to suspicion of academic dishonesty. Violations of academic integrity will result in disciplinary actions ranging from failing grades on assignments and courses to probation, suspension, or dismissal from the university.

The Graduate Honor Code establishes a standard of academic integrity. As such, this code demands a firm adherence to a set of values. In particular, the code is founded on the concept of honesty with respect to the intellectual efforts of oneself and others. Compliance with the Graduate Honor Code requires that all graduate students exercise honesty and ethical behavior in all their academic pursuits at Virginia Tech, whether these undertakings pertain to study, course work, research, extension, or teaching. Details on the Graduate Honor Code can be found at the following Virginia Tech website:

http://ghs.graduateschool.vt.edu/

It is recognized that graduate student population is very culturally diverse. In light of this, the term ethical behavior is defined as conforming to accepted professional standards of conduct, such as codes of ethics used by professional societies in the United States to regulate the manner in which their professions are practiced. The knowledge and practice of ethical behavior shall be the full responsibility of the student. Graduate students may, however, consult with their advisors,

department heads, the Cranwell International Center, or the Graduate School for further information on what is expected of them.

More specifically, all graduate students, while being affiliated with Virginia Tech, shall abide by the standards established by Virginia Tech, as these are described in the Graduate Honor System Constitution. Graduate students, in accepting admission, indicate their willingness to subscribe to and be governed by the Graduate Honor Code and acknowledge the right of the university to establish policies and procedures and to take disciplinary action (including suspension or expulsion) when such action is warranted. Ignorance shall be no excuse for actions that violate the integrity of the academic community.

GRADUATE DEGREE REQUIREMENTS

Students pursuing a graduate degree in the ISE department must satisfy the requirements of the Graduate School, the ISE Department, and, where appropriate, specified track requirements. **It is the responsibility of each student to know the requirements**. Listed in this section are departmental requirements that apply to all ISE graduate curricula. Depending on each student's plan of study there may be more stringent requirements. For a discussion of general Graduate School requirements, the reader should consult the graduate catalog.

Graduate Advisor
The first step in defining the plan of study is the selection of a graduate advisor. MEA and SYSE masters students are assigned to the director of the MEA and SYSE program. Incoming students are assigned a temporary advisor in their general area of interest. For those pursuing a M.S. with thesis or Ph.D. the student should quickly move to determine an appropriate research advisor. In any event, a student's advisor or co-advisor must be a member of the ISE tenure/tenure track faculty and should have particular expertise in the area of research the student intends to pursue. In all cases, the faculty member must give their consent to serve in the capacity of graduate advisor.

Advisory Committee
A graduate advisory committee is required for all MS degrees and for the PhD. The graduate advisor serves as the chair of the student's graduate advisory committee and the student should seek the assistance of their advisor in identifying faculty who might serve on the committee. The committee should be composed of those faculty members who can best assist the student in completing their graduate degree. Each member is added to the student's committee after consenting to serve.

MS advisory committees must include a minimum of three members, at least 2/3 of which must be Virginia Tech tenured or tenure-track faculty (as per Graduate School requirements). An additional departmental-level requirement is that at least two of the members must be tenured or tenure-track faculty in the ISE department (this counts as part of the 2/3 Graduate School requirement). Having a member outside of the ISE department or even outside of Virginia Tech is also encouraged.

PhD advisory committees must include a minimum of four members, at least 2/3 of which must be Virginia Tech tenured or tenure-track faculty (as per Graduate School requirements). An additional departmental-level requirement is that at least two of the members must be tenured or tenure-track faculty in the ISE department (this counts as part of the 2/3 Graduate School requirement). Having a member outside of the ISE department or even outside of Virginia Tech is also encouraged. PhD students are strongly encouraged to identify an advisor by the end of their first year in the program, as this allows them to start their research soon and better achieve the remaining program milestones (as described below).

Committee members are expected to attend meetings as a collective body. Under unusual circumstances a member of the committee may attend a meeting by video or telephone connection. However, the student's advisor must be physically present at all such meetings. Faculty participation on graduate student committees is considered to be an important part of ISE faculty

responsibilities. To this end, ISE faculty are expected to attend all committee meetings for graduate students they advise or on whose committees they serve. In addition, university policies require all members attend a student's final thesis or dissertation defense.

Plan of Study
After identifying a graduate advisor and graduate committee, a student defines their plan of study in consultation with their advisor. The courses listed on the plan of study must include, but are not limited to, all courses required for the degree pursued. A plan of study is required of all students pursuing graduate degrees at Virginia Tech and contains the elements below.

1. List of courses to be completed in the course of degree completion, including the semester and year in which each will be taken.
2. The names and signatures of each member of the student's graduate advisory committee.

For students pursuing a M.S. or M.E.A. degree, the plan of study must be completed and submitted prior to the completion of 24 credit hours or by the end of the second semester of full time enrollment in their graduate program. For students pursuing a doctorate the plan of study must be submitted prior to the completion of 36 credit hours or by the end of the third semester of full time enrollment in their graduate program.

All ISE graduate students must also take **ISE 5024, ISE Seminar**. This seminar is taken the first fall semester of enrollment in the graduate program (it is offered only in the fall term) and is focused on the ISE graduate program, ethics and integrity, faculty, and faculty research areas.

The Graduate School has rules on transfer credit. Consult the graduate catalog for these rules.

The ISE department has rules on transfer credit (beyond the Graduate School rules). Transfer courses may not exceed one-half of graded course credit hours on a plan of study and must be graduate course hours earned at an accredited institution. All transfer courses must have a grade of B or better to be considered for transfer credit. When appropriate, these transfer credits can be used to substitute for required courses if approved by the appropriate course instructor, graduate advisor, and the ISE graduate program director.

Students who have completed a master's degree at another university may be required to take master's level courses in those areas where deficiencies are identified. Where deficiencies are identified, the student's advisory committee will recommend appropriate courses to be included on the plan of study and taken by the student prior to degree completion. Normally, but not in all cases, such courses will carry graduate credit.

In addition to a listing of courses to be taken, the student should write a justification for the inclusion of each member of the committee stating the qualifications each member brings relative to the student's research effort. The committee justification should be attached to the plan of study. The plan of study approval process includes review and signed approval by the student's advisor, graduate committee members, and director of the graduate program. The plan of study is submitted to the ISE Graduate Program Office for electronic approval by the graduate program coordinator and the Graduate School.

Thesis versus Non-thesis *(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)*

For M.S. students, the question often arises as to which path to choose. Each area of study may have a different focus in this regard; however, there are some general guidelines students should consider.

Thesis Pro: A thesis provides a formal experience with research and good preparation for pursuit of a PhD, and faculty may see this experience as a positive if you apply to enter a PhD program. A thesis may be valued by future employers, depending on the field of study.

Thesis Con: You will generally invest at least one summer working on your research, which requires additional tuition investment. The time and effort you put in may not result in a commensurate financial reward on the job. Finally, the ending time of a thesis is uncertain and will most assuredly take a bit longer than the non-thesis route.

Required Graduate Student Milestones
In the course of completing their graduate program, students are required to sequentially complete several milestones and to meet periodically with their graduate advisory committee. These milestones and associated committee meetings are listed below, though additional meetings can be held as needed. As noted earlier (see "Advisory Committee"), committee members are expected to attend all required meetings as a collective body.

1. Preliminary examination (for Ph.D. students only)
2. Research Proposal (for MS thesis & PhD students)
3. Progress Report (for MS thesis & PhD students)
4. Final Examination Defense (for MS thesis & PhD students)

A note regarding ISE Policy: Students, or anyone on their behalf, are strictly forbidden from bringing food or drink to student evaluation meetings (e.g., graduate student progress meetings, proposal defenses, prelim defenses, final defenses, etc.)

Preliminary Examination (for Ph.D. students only). The oral portion of the preliminary examination is a requirement of the Graduate School and must be successfully completed by all Ph.D. students. The Graduate School requires this to be completed at least six months prior to completing the Ph.D. degree (final defense of the dissertation). The ISE department expects the Preliminary Examination to be completed before the end of a student's 5th semester in the graduate program. It is expected that the student will complete all (or the vast majority) of their coursework prior to beginning the preliminary examination.

The examination includes both written and oral parts for ISE Ph.D. students. The intent of the examination is to establish that the student is qualified to pursue creative, original, independent research at a level expected of Ph.D. students. This examination is an essential demonstration of a student's ability to successfully complete his or her Ph.D. Questions can cover any aspect of ISE study desired by the committee so adequate preparation for the examination is critical for

success. ISE faculty considers this a major milestone and decision point for both students and faculty regarding the appropriateness of a student continuing in the program.

The written portion of the examination requires two weeks for completion. The oral portion of the examination is administered at least two weeks after completion of the written portion and must be scheduled through the Graduate School. Students must be registered during the semester the oral portion of the examination is taken and may not schedule the preliminary examination until they have a plan of study that has met final approval by the Graduate School. The oral preliminary examination must be scheduled through the Graduate School at least two weeks prior to the date the exam will be held. The exam is scheduled online using the Graduate School's electronic scheduling and signature system (ESS), which can be accessed at the following web site:

https://ess.graduateschool.vt.edu/pages/login.php

Graduate School policy states, "Requests to schedule examinations must include the time, date, building and room number, title of dissertation or thesis, and the names and email addresses of the Examining Committee. *These requests are due in the Graduate School at least two weeks before the examination date requested.*"

Committee members will have *up to 3 days* to approve the online examination/evaluation scheduling request from the time the request is submitted by the student. If the online scheduling request form is not approved by all committee members in the Electronic Signature System in this time frame, the committee, student, and academic unit administrative contacts will be notified that the examination/evaluation request will be *cancelled* and will need to be rescheduled.

As a reminder, no examination or evaluation should be conducted if the committee has not received electronic notification from the Graduate School that the examination/evaluation has been officially scheduled. Please contact the Graduate School at least two days prior to a requested examination/evaluation date if you have not received the official notification of scheduling.

Graduate School policies on scheduling examinations/evaluations can be found in the Graduate Catalog:

http://graduateschool.vt.edu/graduate_catalog/policies.htm?policy=002d14432c654287012c6542e3630013

The preliminary examination is to be solely the work of the Ph.D. candidate. No outside assistance is allowed, including no proofreaders or writing assistance. To do otherwise will be considered a violation of the honor code.

The student's advisory committee administers the preliminary examination and one negative vote by a committee member is permitted for successful completion of the examination. All members of the student's advisory committee must attend the oral portion of the examination. If performance on the preliminary examination is unsatisfactory, one full semester must lapse (15

weeks) before the examination is administered a second time. Students failing the preliminary examination twice will be dismissed from the program. The result of the examination is recorded in the ESS system. Each member of the student's advisory committee must approve the exam result in the ESS system. <u>Advisory committees reserve the right to alter a plan of study based on performance on the preliminary exam.</u>

Research Proposal (for M.S./thesis & Ph.D. students). Students pursuing a thesis M.S. or Ph.D. are required to complete research in the course of graduate study. ***Note that the ISE Department expects the Ph.D. proposal to be defended successfully before the end of the student's 3rd year in the graduate program. Further, it is expected that the M.S. and Ph.D. research will be proposed to the committee before substantial aspects of the work are completed.*** To initiate the research effort, the student is required to prepare a research proposal that describes the content of the research, the outcome anticipated, the contribution to the field of endeavor, and the creative content of the effort. This proposal must be in written form and must be presented to his or her advisory committee at a meeting where all committee members are present. The signatures of each committee member on the proposal approval form signify approval of the proposed research effort. This form is submitted to the ISE Graduate Program Office upon completion.

The nature and level of the research effort depends on the degree sought. Thesis research leading to the M.S. degree is, in general, applied but should represent an original contribution to the student's field of interest. A student pursuing a Ph.D. degree should demonstrate, through the dissertation, the ability to carry out original and creative research. The results of the research should be sufficiently significant to be publishable in a major technical journal. The writing style, grammar, and spelling of the thesis or dissertation should reflect a high level of skill in written communication.

Progress Meeting (for M.S. thesis & Ph.D. students). Between the research proposal and the final examination each student is required to provide a summary of progress to their advisory committee at a progress meeting. This meeting is expected to be held before the majority of the M.S. or Ph. D. research is completed. The advisory committee signs the progress report form and this form is submitted to the ISE Graduate Program Office upon completion.

Final Examination - Defense. (for M.S. thesis and Ph.D. students). All graduate students pursuing an M.S. thesis or Ph.D. degree are required to pass a final examination or defense. For students pursuing a Ph.D. or a thesis M.S. this is an oral examination and is administered by the advisory committee. The examination is also a requirement of the Graduate School and must be administered during a semester in which the student is registered. ***Note that the ISE Department expects Ph.D. students to defend their dissertation successfully within four years after enrolling in the graduate program. The Department requires that the written dissertation or thesis be submitted to the committee at least two weeks prior to the examination.***

Graduate School policy states, "Requests to schedule final examinations must include the time, date, building and room number, title of dissertation or thesis, and the names and email addresses of the Examining Committee. These requests are due in the Graduate School ***at least two weeks*** before the examination date requested."

Committee members will have ***up to 3 days*** to approve the online examination/evaluation scheduling request from the time the request is submitted by the student. If the online scheduling request form is not approved by all committee members in the Electronic Signature System in this time frame, the committee, student, and academic unit administrative contacts will be notified that the examination/evaluation request will be ***cancelled*** and will need to be rescheduled.

Approval of a final examination request indicates that the committee member has received and read the thesis or dissertation document and agrees that the document is ready for defense. This means that no additional work including additional data collection and/or analysis is needed, only minor edits to the document after the defense as may be necessary.

As a reminder, no examination or evaluation should be conducted if the committee has not received electronic notification from the Graduate School that the examination/evaluation has been officially scheduled. Please contact the Graduate School at least two days prior to a requested examination/evaluation date if you have not received the official notification of scheduling.

Graduate School policies on scheduling examinations/evaluations can be found in the Graduate Catalog:

 http://graduateschool.vt.edu/graduate_catalog/policies.htm?policy=002d14432c654287012c654 2e3630013

The exam is scheduled online using the Graduate School's electronic scheduling and signature system (ESS), which can be accessed at the following web site:

https://ess.graduateschool.vt.edu/pages/login.php

To pass the final examination, a degree candidate must have a favorable vote from a majority of the examining committee, with a maximum of one negative vote. If a student fails the final examination, there must be a lapse of one full semester (15 weeks) before rescheduling the examination. A student is allowed no more than two opportunities to pass the final examination.

The result of the examination is recorded in the ESS system. Each member of the student's advisory committee must approve the exam result in the ESS system.

Final Examination. (for M.S. non-thesis students). All graduate students pursuing an M.S. non-thesis are required to schedule a final examination with the Graduate School. There is no examination for the ISE or SYSE non-thesis M.S. degrees. The examination is a requirement of the Graduate School and must be scheduled during a semester in which the student is registered. This is normally done in the student's final semester of enrollment in the graduate program.

Graduate School policy states, "Requests to schedule final examinations must include the time, date, building and room number, and the names and email addresses of the Examining Committee. These requests are due in the Graduate School ***at least two weeks*** before the

examination date requested." The ISE Graduate Program Office will email instructions for date, time, building, and room number early in each semester.

Committee members will have **up to 3 days** to approve the online examination/evaluation scheduling request from the time the request is submitted by the student. If the online scheduling request form is not approved by all committee members in the Electronic Signature System in this time frame, the committee, student, and academic unit administrative contacts will be notified that the examination/evaluation request will be **cancelled** and will need to be rescheduled.

Approval of a final examination request indicates that the committee member has received and read the thesis or dissertation document and agrees that the document is ready for defense. This means that no additional work including additional data collection and/or analysis is needed, only minor edits to the document after the defense as may be necessary.

As a reminder, no examination or evaluation should be conducted if the committee has not received electronic notification from the Graduate School that the examination/evaluation has been officially scheduled. Please contact the Graduate School at least two days prior to a requested examination/evaluation date if you have not received the official notification of scheduling.

Graduate School policies on scheduling examinations/evaluations can be found in the Graduate Catalog:

 http://graduateschool.vt.edu/graduate_catalog/policies.htm?policy=002d14432c654287012c6542e3630013

The exam is scheduled online using the Graduate School's electronic scheduling and signature system (ESS), which can be accessed at the following web site:

https://ess.graduateschool.vt.edu/pages/login.php

To pass the final examination, a degree candidate must have a favorable vote from a majority of the examining committee, with a maximum of one negative vote. If a student fails the final examination, there must be a lapse of one full semester (15 weeks) before rescheduling the examination. A student is allowed no more than two opportunities to pass the final examination.

The result of the examination is recorded in the ESS system. Each member of the student's advisory committee must approve the exam result in the ESS system.

Thesis and Dissertation

The thesis (M.S.) or dissertation (Ph.D.) must be submitted to the student's advisory committee at least two weeks prior to the final examination. The thesis or dissertation must be approved by all members of a student's advisory committee, usually upon successful completion of the final examination. If a committee member does not approve the thesis or dissertation, upon the faculty member's request, a written dissenting opinion can be bound with the final document. A successful candidate is allowed a maximum of one negative vote.

Webster's New World College Dictionary defines a dissertation as "a formal and lengthy discourse or treatise on some subject, esp. one based on original research and written in partial fulfillment of requirements for a doctorate," but it is much more than that. It is the final product representing the research efforts of the PhD candidate. It is an independent work, guided by a faculty research mentor. It must contribute to the body of knowledge in the specific, narrow research area the candidate and his or her research advisor have selected. Peers in the field, represented by a student's research committee, evaluate the dissertation. Candidates should expect a rigorous examination, both at the proposal and the defense stage, from the committee. The final defense is so called because the candidate must successfully provide a defense of each step of their research; their topic, their methods, their analysis, and their results. For many students this represents the most comprehensive piece of research they will undertake.

Each Ph.D. student is required to prepare a paper suitable for publication in an appropriate archival journal. The paper must be based on results achieved in the course of dissertation research. The paper should be submitted to the student's advisory committee at, or before, the final examination. In addition, each Ph.D. student must prepare and present an open seminar on their research as a requirement for degree completion. Scheduling this is done in cooperation with the advisor.

Theses and dissertations must be filed electronically with the Graduate School through the Graduate School's electronic scheduling and signature system (ESS). The approval of the ETD is recorded in the ESS system. Each member of the student's advisory committee must approve the ETD in the ESS system.

For information on thesis and dissertation preparation, formatting and electronic submission, please see the following website: http://etd.vt.edu/

The student, advisor, committee members, and the ISE Graduate Program Director are notified once the ETD process is complete.

Continuing from the MS to the Ph.D.

Students in the master's program who wish to remain in the ISE department to pursue a Ph.D. degree apply to the Ph.D. program. They must make their intention known by submitting a formal application to the Graduate School. One of the three required recommendation letters for the application must be from a faculty member willing to serve as at least the initial Ph.D. advisor. The graduate admissions committee will review the student's academic performance and a decision on admission to the Ph.D. program will be made upon completion of the review. If accepted the student will be officially notified by the Graduate School.

DOCTOR OF PHILOSOPHY (PHD) PROGRAM

The Grado Department of Industrial and Systems Engineering has a reputation as one of the top ISE Ph.D. programs in the world. This reputation stems from the cutting edge research conducted here by the collaboration of a strong and experienced faculty with the top graduate students in the field. Doctoral students in ISE experience rigorous academic study requiring independent investigation that results in original scholarly work of the highest quality. Graduates are well prepared for positions in both academia and the private or public sector.

Prospective Ph.D. students should have a strong academic background that is commensurate with their desired field of study within the department. Students will need to select one of the Ph.D. Concentrations that are listed below. Please go to the department website (http://www.ise.vt.edu/academics/graduate/phd/index.html) to obtain more details about the respective domains, curriculum requirements, and specific faculty supporting each concentration.

Common Requirements for Concentrations

The following apply to all concentrations. Please note, however, that several of these are minimum requirements that may be exceeded by the requirements of a given concentration, and that additional requirements may exist in some concentrations.

- Students who entered the ISE Ph.D. program prior to the Fall of 2016 may follow earlier Ph.D. requirements ("tracks") or switch to one of the current Concentrations
- All Ph.D. student must complete a minimum of 36 graded credit hours, including 24 grade ISE course hours (post BS, and not including ISE 5024. Note that ENGR 5004 and ENGR 5014 can be counted toward the ISE course-hour requirement, unless otherwise indicated for a given concentration
- P/F and other non-graded courses cannot be counted toward minimum credit-hour requirements
- All required courses in a concentration must be taken for a grade (i.e., A-F)
- Courses not listed as pre-approved electives in a concentration may be taken, or substitutions for required concentration courses made, pending approval of the student's Ph.D. advisory committee

Ph.D. Program Concentrations

1. Cognitive Engineering
2. Human Factors of Systems & Product Design
3. Management Systems Engineering
4. Manufacturing Systems Engineering
5. Occupational Ergonomics and Safety
6. Operations Research

MASTER OF SCIENCE DEGREES

(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)

1. HUMAN FACTORS ENGINEERING AND ERGONOMICS
<u>**Thesis:**</u>
Master's level students with thesis are required to complete four required core courses, a minimum of four elective courses, and six hours of thesis work. A listing of pre-approved tracks with suggested programs of study are provided in tables that follow. These tracks are designed to allow the student to specialize in a particular area within HFEE, but also allow some flexibility in course selection. Deviations from the suggested tracks are possible with approval of the HFEE faculty.

Course Number	Course Title	Credit Hours
ISE 5604	Human Information Processing	3
ISE 5605	Human Factors System Design I	3
ISE 5614	Human Physical Capabilities	3
ISE 5615	Human Factors Research Design I	4
ISE 5994	Research Thesis	6
Electives	(See Pre-Approved Tracks Table)	12
	Total Hours	**31**

Pre-Approved Tracks (Electives)

A minimum of four courses can be chosen from any one of these pre-approved tracks and used as electives. At least two of the electives must be ISE courses and at least one of these ISE courses must be an HFEE course. No more than two electives courses outside of ISE may be used toward meeting degree requirements.

Cognitive Ergonomics	Human-Computer Interaction
*ISE 5694 Macroergonomics	*ISE 5714 Usability Engineering
*ISE/CS 5714 Usability Engineering	*ISE 6604 Visual Displays
*ISE 5794 Independent Study/Special Topics	*ISE 6614 Human Computer Systems
STAT 4504 Applied Multivariate Statistics	CS 4624 Multimedia, Hypertext, and Information Access
PSYC 5344 Cognitive Psychology	CS 5734 Computer-Supported Cooperative Work
	CS 5724 Models and Theories of Human Computer Interaction

Macroergonomics	Methods
*ISE 5694 Macroergonomics	ISE 5424 Simulation
CS 5734 Computer-Supported Cooperative Work	EDRE 6614 Qualitative Methods in Educational Research
PSYC 5125 Organizational Psychology	PSYC 5134 Advanced Psychometric Theory

STAT 4505 Applied Multivariate Statistics
ENGR 5104 Applied Systems Engineering
SOC 6204 Survey Research Methods
STAT 4504 Applied Multivariate Statistics
STAT 5644 Nonparametrics

Occupational Biomechanics	Sensory and Perception
*ISE 4624 Work Physiology	*ISE 5644 Human Audition and Auditory Display Design
ISE 5104 Operations Research or ISE 5405 Optimization	*ISE 6604 Human Factors in Visual Display
ISE 5424 Simulation	PSYC 5144 Sensory Processes
ESM 4204 Musculoskeletal Biomechanics and Biologic Control	PSYC 4074 Sensation and Perception
BMES 5034 Introduction to Biomedical Engineering	CS 5754 Virtual Environments
HNFE 4844 Exercise & Neuromuscular Performance	
HNFE 5814 Skeletal-Muscular Function in Exercise	

Safety	Telecommunications
*ISE 4644 Occupational Safety & Hazard Control	*ISE 5714 Usability Engineering
* ISE 5644 Human Audition and Auditory Display Design	EDCI 5604 Distance Learning
*ISE 5674 System Safety	CS 5516 Computer and Network Architecture
ACIS 5514 Management of Information Systems	CS 5734 Computer-Supported Cooperative Work
ACIS 5594 Web-based Applications and Electronic Communications	

Transportation	Work-Related Musculoskeletal Disorders
*ISE 6604 Human Factors in Visual Displays	*ISE 4624 Work Physiology
*ISE 5644 Human Audition and Auditory Display Design	*ISE 5694 Macroergonomics

*ISE 5674 System Safety	*ISE 4644 Occupational Safety
*ISE 5714 Usability Engineering	STAT 4504 Applied Multivariate Statistics or 5644 Nonparametrics
*ISE 6614 Human Computer Systems	HNFE 4844 Exercise & Neuromuscular Performance
CEE 5640 Highway Transportation Safety	HNFE 5724 Epidemiology
	BMES 5064 Quantitative Organ Systems Physiology

*Denotes an HFEE course

Non-Thesis : *(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)*

A coursework-only Master's level curriculum is available, and will typically be selected by students pursuing an application-oriented degree and without an interest in continuing for a doctoral degree. Non-thesis M.S. students are required to complete at least 31 credit hours of course work, as described in the table below. Deviations from the suggested courses are possible with approval of the HFEE faculty.

COURSE# AND TITLE	HOURS
All of the following or their equivalent are required:	**13**
ISE 5604 Human Information Processing	3
ISE 5605 Human Factors System Design I	3
ISE 5614 Human Physical Capabilities	3
ISE 5615 Human Factors Research Design I	4
Elective Courses:	**≥ 18**
At least 4 Additional Graduate Level ISE-HFEE courses	≥ 12
At least 1 non-HFEE ISE Graduate Level course	≥ 3
At least 1 non-ISE Graduate Level course	≥ 3
Total Hours	**≥ 31**

2. GENERAL INDUSTRIAL ENGINEERING

Degree programs and curricula requirements: *(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)*

There are two master's degree programs in the general track: the M.S. non-thesis (MSNT) and M.S. thesis (MST). The curricula in each case include required courses in ISE and technical elective courses. The elective courses are of two types: 1) ISE electives and 2) general technical electives. Both the set of ISE electives and the set of general electives will be specifically determined by the student in direct consultation with his or her advisor and committee. A graduate advisory committee may require a student to take more course credits than the minimum specified here. *The student should consult the graduate catalog to determine pre-requisites for any courses*

specified. Students without a sufficient mathematics and engineering background will be required to take preparatory coursework in these areas that will not count for graduate credit.

Plan of study: The ISE departmental requirements for submitting the plan of study for approval are described in an earlier section of this manual—students should review these requirements carefully. The plan of study is developed in conjunction with the student's advisor and is approved by the student's committee and the ISE Graduate Program Director.

The master's degree programs consist of at least **30 credit hours** and include core, required courses, ISE electives, and general technical electives. In addition, some students, particularly those holding a non-engineering B.S. or non-technical B.A. degrees, should be prepared to take preparatory courses, if necessary, that are not counted for graduate credit.

Option #1 - Available only to students enrolled prior to Spring 2018. (***This option will be phased out at the end of fall 2017. Any students enrolled fall 2017 or earlier may choose this option or may choose to follow option # 2 below.***)

Minimum hours for the two IE Track degree tracks are distributed as follows:

	MSNT	MST
IE Track core courses	9	9
ISE elective courses	15	9
General technical elective courses	6	6
Research (MST/ISE 5994)	—	6
Total	**30**	**30**

Thesis

The MST is designed to provide an opportunity for in-depth study and independent research with an ISE faculty member. The MST is a 4 semester program for students entering with adequate academic preparation. All students pursuing the MST should begin, early in their program, to identify a major advisor who will direct the research effort. The research undertaken will be aligned with the research interest of the major advisor.

Curriculum

The curriculum is design to provide maximum flexibility in selecting general technical electives, within the specified guidelines, to define a program of study to support the planned research and graduate study. ISE electives are any graduate-level ISE class, with exceptions as noted. General technical electives are selected by the student's advisory committee, in consultation with the student in order to fit the interests and goals of the students, and may be from other engineering disciplines, or disciplines outside of engineering. A student's graduate advisory committee may require the student to take courses in particular areas to fulfill remedial needs.

Required Courses

Both the MSNT and MST programs require the same set of three IE Track core courses and are presented in the table below.

Core Courses and Schedule

Fall I	**Spring I**
ISE 5405 (optimization I) ISE 5034 (Mathematical Probability & Statistics) Elective(s)	ISE 5044 (Production Systems Analysis) Elective(s)
Fall II (and Spring II if needed) Elective(s) or thesis	**3 Core courses** Non-thesis: **30** credit hours (of which **9** are IE Track core courses, **15** are ISE electives, and **6** are general technical electives) Thesis: **30** credit hours (of which **9** are IE Track core courses, **9** are ISE electives, **6** are general technical electives, and **6** are thesis research credit hours).

ISE and General Technical Elective Courses (5 courses for the MSNT or 3 courses for the MST)

Elective exceptions listed below. These courses CANNOT be used.

ISE 5104	Operations Research
ISE 5114	Case Studies in Industrial Engineering
ISE 5134	Management Information Systems
ISE 5154	Applied Human Factors Engineering
ISE 5164	Technology Transfer
ISE 5174	Engineering Program and Project Management

Option #2 – Only option available after spring 2018.

Required:
ISE 5405 Optimization OR ISE 5104 Operations Research
Note: ISE 5405 is a pre-requisite for several more advanced courses; students interested in such courses should thus not take ISE 5104.

Select at least 4 courses from the following list:
ISE 5204 Manufacturing Systems
ISE 5034 Math Probability and Statistics
ISE 5424 Simulation
ISE 5015 Management of Organizational Systems
ISE 4214 Lean Manufacturing
ISE 5474 Statistical Quality Control

ISE 5605 Human Factors System Design
ENGR 5104 Applied Systems Engineering

For the thesis:
Complete an additional three courses, which can be any combination of additional courses from the list above and/or from pre-approved electives.
Complete up to 10 hours is ISE 5994 Research and Thesis

For the non-thesis degree:
Complete at least five additional courses, which can be any combination of additional courses from the list above and/or from pre-approved electives.

Pre-Approved Electives
Pre-approved electives are listed in the Ph.D. concentrations on the ISE web site. Any of these pre-approved electives can count towards a degree in the General Industrial Engineering M.S. degree. Ph.D. concentrations: https://ise.vt.edu/academics/graduate/phd.html

3. MANAGEMENT SYSTEMS ENGINEERING

The master's degree programs consist of at least 30 credit hours and include core, required courses (covering a broad range of IE topics), MSE required courses (in-depth coverage of management systems engineering topics), and technical electives. In addition, some students, particularly those holding a non-engineering BS degree, should be prepared to take preparatory courses that are not counted for graduate credit.

Minimum hours for the two master's programs are distributed as follows:

	MST	MSNT
Core courses	18	18
Elective courses	6	12 (3 hrs. min. in ISE)
Research (MST/ISE 5994)	6	—
Total	30	30

Non-Thesis *(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)*
The MSNT is designed to provide coverage of a wide range of management systems engineering topics, and an exposure to a range of industrial engineering topics, through required and elective courses. Most students are encouraged to pursue this track. This is a 12-18 month program serving as a technical alternative to the MST.

Thesis
The MST is designed to provide in-depth coverage of management systems engineering topics and experience in performing independent research in a chosen area of interest approved by the graduate advisory committee. The MST is a 21-24 month program. All students pursuing the MST must take core, required courses in industrial engineering and in management systems

engineering and must secure an advisor who will direct the research effort—very few students are accepted into the MST track. The requirements in this section apply to students having a BS in engineering.

Curriculum

The curriculum is designed to provide maximum flexibility in selecting technical electives, within the specified guidelines, to define a program of study to support the planned research and graduate study. Technical electives may be taken from other graduate tracks in ISE, other engineering disciplines, or disciplines outside of engineering in support of the research. A student's graduate advisory committee may require the student to take courses in particular areas to fulfill technical requirements or remedial needs.

Required Courses

Both the MST and MSNT programs have similar core requirements within ISE and the management systems track. These requirements are presented in the tables below.

Required Courses (5 courses)	
ISE 5015 or 5124	Mgt of Change, Innovation & Performance in Organizational Systems I (5015) or Management of Quality and Reliability (5124)
ISE 5016 or 5144	Mgt of Change, Innovation & Performance in Organizational Systems II (5016) or Performance and Productivity Measurement and Evaluation
ENGR 5104	Applied Systems Engineering
ENGR 5004	The Systems Engineering Process
ISE 5024	ISE Seminar (1 hour class, no degree credit)

Core ISE Courses (2 courses)	
Select one course from any two of the three tracks below	
Operations Research	
ISE 54XX	
ISE 5104	Operations Research (special approval only)
Manufacturing Systems Engineering	
ISE 52XX or 53XX	
Human Factors Engineering	
ISE 56XX or 57XX	
ISE 5154	Applied Human Factors Engineering

Technical Electives

Six (MST) or twelve (MSNT) hours of technical electives are required. These electives must be selected to provide support appropriate for master's level study and meet ISE and Graduate School guidelines. It is required that students in the MSNT track take a minimum of three hours of

electives from among ISE courses. A particular student's electives will be determined in consultation with the student's advisor and graduate policy committee, where appropriate.

4. MANUFACTURING SYSTEMS ENGINEERING

Non-Thesis Curriculum *(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)*

The Manufacturing Systems Engineering **Master of Science (M.S.) non-thesis degree** is designed to provide an in-depth coverage of a wide range of topics related to manufacturing systems engineering. Appropriate courses are included in this program to introduce to the student quantitative tools and techniques to enable solution of a well-defined manufacturing problem. The M.S. non-thesis degree in Manufacturing Systems Engineering is intended primarily for those wishing advanced knowledge and problem-solving skills for application in industry.

In order to be more closely associated with a specific domain, students may elect to follow a particular area of concentration. These are groups of courses reflecting both the interests and specializations of the Manufacturing Systems Engineering faculty and current industrial demands and trends. Three areas of concentration currently offered are:

Computer-Integrated-Manufacturing (*CIM*) *and General Manufacturing*: Computer-Integrated Manufacturing involves the use of computers and associated equipment to integrate the flow of information across the various activities performed in manufacturing organizations. The CIM track has been developed to provide students with the advanced knowledge and skills required to design, implement, and analyze CIM systems both in theory and in practice. Besides CIM, General Manufacturing aims to introduce the students to lean manufacturing, semiconductor manufacturing and flexible manufacturing systems.

Robotics and Automation: The robotics and automation track involves the design and application of manufacturing systems that integrate robots and other automation technologies into manufacturing systems for efficient processes and material handling operations. This track includes courses which emphasize both the technologies of automation and integration aspects. Additionally, courses in computer aided design and computer systems technologies are often taken by students interested in this track.

Production Systems: Production planning and control involves the procurement, production and distribution-related functions of a manufacturing facility. Some specific problem areas include production scheduling, aggregate planning, facilities planning, production and inventory control, process planning and forecasting. This track is designed to introduce to the student the tools and techniques of this area for application to real-world problems as well as to build a theoretical foundation to do research in this area.

Required courses (core; 6 hours)

Course No.	Course Title	Credit Hrs.
ISE 5204	Manufacturing Systems Engineering	3
ISE 5405	Optimization I	3
	Total Hours	6

Required courses (menu; 6 hours)

Select two of the following four courses (the other courses can be used as elective courses).

Course No.	Course Title	Credit Hrs.
ISE 4264	Automation	3
ISE 4214	Lean Manufacturing	3
ISE 5244	Facilities Planning & Material Handling	3
ISE 5454	Production Planning & Control	3
ISE 5044	Production Systems Analysis	3

Electives (18 Hours)

In addition to the core courses, **six or more** elective courses are required. No more than 6 credit hours at the 4000 level can be taken. A suggested list of ISE course electives is given below. Also, three sets of courses belonging to specialized areas of concentrations are identified below that are often taken by M.S. non-thesis students. Courses may be selected from within the department or from a related area, as long as such courses are approved by the student's advisory committee. No more than one (1) College of Business course may be used to fulfill this requirement.

ISE course electives		
Course No.	Course Title	Credit Hrs.
ISE 4264	Automation	3
ISE 4214	Lean Manufacturing	3
ISE 5264	Semiconductor Manufacturing	3
ISE 5314	Industrial Applications of Robotics Devices	3
ISE 5424	Simulation	3
ISE 5244	Facilities Planning & Material Handling	3
ISE 5454	Production Planning & Control	3
ISE 6284	Advanced Topics in Manufacturing Systems Engr.	3
ISE 6434	Scheduling and Sequencing Theory	3

Computer Integrated Manufacturing and General Manufacturing Electives		
Course No.	Course Title	Credit Hrs.
ISE 4214	Lean Manufacturing	3
ISE 5264	Semiconductor Manufacturing	3
ISE 5424	Simulation I	3

| ISE 5244 | Facilities Planning & Material Handling | 3 |
| ISE 5454 | Production Planning & Control | 3 |

Robotics and Automation Electives		
Course No.	Course Title	Credit Hrs.
ISE 4264	Automation	3
ME 4524	Introduction to Robotics and Automation	3
ME 4634	Introduction to Computer-Aided Design and Mfg.	3
ME 5604	Computer-Aided Design I	3
ME 6604	Computer-Aided Design II	3
EE 5554	Theory and Design of Computer Vision Systems	3

Production Systems Electives		
Course No.	Course Title	Credit Hrs.
ISE 4214	Lean Manufacturing	3
ISE 5414	Random Process	3
ISE 5424	Simulation I	3
ISE 5264	Semiconductor Manufacturing	3
ISE 5454	Production Planning & Control	3
CS 5804	Artificial Intelligence	3
ISE 6404	Graph Theory and Network Flows	3
ISE 6424	Dynamic Programming	3
ISE 6434	Scheduling and Sequence Theory	3

Total Credit Hours Required for M.S. Non-Thesis Curriculum: 30

Thesis Curriculum

The Manufacturing Systems Engineering **Masters of Science (M.S.) thesis degree** is designed to provide an in-depth coverage of a particular range of topics related to manufacturing systems engineering, and experience in performing independent research in a chosen area of interest approved by the student's advisory committee. The culmination of this research is the M.S. thesis. The M.S. degree in Manufacturing Systems Engineering is intended primarily for those desiring to develop higher-level analysis, synthesis, and evaluation skills in a particular domain of manufacturing systems engineering. Degreed students typically seek advanced industrial positions or continue towards the Ph.D. degree.

In order to be more closely associated with a specific domain, students may elect to follow a particular area of concentration. (Please refer to these areas and the courses offered in them under the M.S. non-thesis curriculum description).

Required courses (core; 6 hours)

Course No.	Course Title	Credit Hrs.
ISE 5204	Manufacturing Systems Engineering	3

ISE 5405	Optimization I	3
	Total Hours	6

Required courses (menu; 6 hours)
Select two of the following four courses (the other courses can be used as elective courses).

Course No.	Course Title	Credit Hrs.
ISE 4264	Automation	3
ISE 4214	Lean Manufacturing	3
ISE 5244	Facilities Planning & Material Handling	3
ISE 5454	Production Planning & Control	3
ISE 5044	Production Systems Analysis	3

Electives (12 Hours)

Four or more courses are required. These may be selected from one of the concentration areas offered (see M.S. non-thesis electives). Courses may be selected from within the department or from a related area, as long as such courses are approved by the student's advisory committee. No more than 6 credit hours at the 4000 level can be taken. Also, no more than one (1) College of Business course may be used to fulfill this requirement).

Research Requirements (6 Hours)

Six or more credit hours of M.S. thesis research (*ISE 5994: Research and Thesis*) are required. The student's advisor (or at least one of the co-chairs) must be a tenure/tenure track faculty member from the Manufacturing Systems Engineering area.

Total Credit Hours Required for M.S. Thesis Curriculum: 30

5. OPERATIONS RESEARH
The required courses for the M.S. degree are given in the following table:

Course No.	Course Title	Credit Hrs.
ISE 5405	Optimization I	3
ISE 5406	Optimization II	3
ISE 5414	Random Processes	3
ISE 5424	Simulation	3
ISE 5034	Mathematical Probability & Statistics	3

Thesis Curriculum

The thesis-based M.S. program requires 30 credit hours, including 24 course-credit hours (of which 15 are for required courses) and up to 6 thesis hours. Students must select 9 credit hours of elective course work from either the following list of ISE courses, or from the table on the following page, *or any relevant graduate courses offered by the university subject to the approval of the student's committee.*

Course No.	Course Title	Credit Hrs.
ISE 4424	Logistics Engineering	3
ISE 5204	Manufacturing Systems Engineering	3
ISE 5244	Facilities Planning and Material Handling	3
ISE 5434	Econ. Evaluation of Industrial Projects	3
ISE 5454	Production Planning and Control	3
ISE 5464	Queuing Theory I	3
ISE 5474	Statistical Theory of Quality Control	3
ISE 5484	Modeling Processes in Operations Research	3
ISE 6404	Graph Theory & Network Flows	3
ISE 6414	Integer Programming	3
ISE 6424	Dynamic Programming	3
ISE 6434	Scheduling and Sequence Theory	3
ISE 6464	Inventory Theory	3
ISE 6454	Adv Topics in Supply Chain & Operations Mgmt	3
ISE 6464	Queuing Networks	3
ISE 6474	Reliability Theory	3
ISE 6494	Advanced Simulation	3
ISE 6504	Markov Renewal and Related Processes	3
ISE 6514	Advanced Topics in Math Programming	3
ISE 6524	Advanced Topics in Engineering Economy	3

CS/Math 5485	Numerical Analysis and Software I	3
CS/Math 5486	Numerical Analysis and Software II	3
MATH 4225	Elementary Real Analysis I	3
MATH 4226	Elementary Real Analysis II	3
MATH 5226	Real Analysis II	3
MATH 5454	Graph Theory	3
MATH 5464	Combinatorics	3
MATH 5524	Matrix Theory	3
MATH 5545	Calculus of Variations and Optimal Control Theory I	3
MATH 5546	Calculus of Variations and Optimal Control Theory II	3
STAT 5124	Linear Models Theory	3
STAT 5204	Experimental Design & Analysis I	3
STAT 5424	Statistical Decision Theory	3
STAT 5434	Markov Chains & Renewal Theory	3
STAT 5504	Multivariate Statistical Methods	3
STAT 5514	Regression Analysis	3
STAT 5554	Variance Components	3
STAT 5574	Response Surface Design and Analysis I	3

STAT 6106	Measure and Probability	3
STAT 6424	Multivariate Statistical Analysis	3
STAT 6574	Response Surface Design and Analysis II	3
STAT 6504	Experimental Design II	3
CS 5114	Theory of Algorithms	3
	Any ISE Department course that is approved for graduate credit	

Non-Thesis Curriculum *(Note: As of fall 2018 the M.S. non-thesis degree will no longer be available. The coursework only non-thesis M.S. degree will be offered as a Master of Engineering (M.Eng.) degree.)*

Students selecting the non-thesis track must complete 30 credit hours of coursework including 15 credits of required courses as enumerated in the following table.

Course No.	Course Title	Credit Hrs.
ISE 5405	Optimization I	3
ISE 5406	Optimization II	3
ISE 5414	Random Processes	3
ISE 5424	Simulation	3
ISE 5034	Mathematical Probability & Statistics	3

Students in the non-thesis track must then complete 15 credits of courses at least 6 credits of which must be selected from the following list.

Course No.	Course Title	Credit Hrs.
ISE 4424	Logistics engineering	3
ISE 5204	Manufacturing systems engineering	3
ISE 5244	Facilities planning and material handling	3
ISE 5434	Econ. evaluation of industrial projects	3
ISE 5454	Production planning and control	3
ISE 5464	Queuing theory	3
ISE 5474	Statistical theory of quality control	3
ISE 5484	Modeling processes in OR	3
ISE 6404	Graph theory & network flows	3
ISE 6414	Integer programming	3
ISE 6424	Dynamic programming	3
ISE 6434	Scheduling & sequencing theory	3
ISE 6464	Inventory Theory	3
ISE 6454	Adv Topics in Supply Chain & Operations Mgmt	3
ISE 6464	Queuing networks	3
ISE 6474	Reliability theory	3
ISE 6494	Advanced Simulation	3
ISE 6504	Markov renewal & related processes	3

ISE 6514	Advanced topics in math programming	3
ISE 6524	Advanced topics in engineering economy	3

Non-thesis students may elect up to 9 credit hours of coursework from the following table *or any relevant graduate courses offered by the university subject to the approval of the student's advisory committee.*

CS/Math 5485	Numerical analysis and software I	3
CS/Math 5486	Numerical analysis and software II	3
MATH 4225	Elementary Real Analysis I	3
MATH 4226	Elementary real analysis II	3
MATH 5226	Real analysis II	3
MATH 5454	Graph theory	3
MATH 5464	Combinatorics	3
MATH 5524	Matrix theory	3
MATH 5545	Calculus of variations and optimal control theory I	3
MATH 5546	Calculus of variations and optimal control theory II	3
STAT 5124	Linear models theory	3
STAT 5204	Experimental design & analysis I	3
STAT 5424	Statistical decision theory	3
STAT 5434	Markov chains & renewal theory	3
STAT 5504	Multivariate statistical methods	3
STAT 5514	Regression analysis	3
STAT 5554	Variance components	3
STAT 5574	Response surface design and analysis I	3
STAT 6106	Measure and probability	3
STAT 6424	Multivariate statistical analysis	3
STAT 6574	Response surface design and analysis II	3
STAT 6504	Experimental design II	3
CS 5114	Theory of algorithms	3
	Any ISE Department course that is approved for graduate credit	

6. ENGINEERING ADMINISTRATION (MEA)

The Master's of Engineering Administration (MEA) degree program is designed for those who wish to prepare for career opportunities in the operation and management of research, engineering, and technology development enterprises. Graduates of this program are prepared for middle- and senior-level leadership and management positions in technology-centric enterprises, such as Engineering Manager, R&D Manager/Director, Technology Manager, Chief Technology Officer, Systems Engineering Manager, Manager of Product Engineering, Program Manager, Project Manager, and Manager of Technology Acquisitions.

This MEA degree is a non-thesis program that requires completion of a minimum of 10 courses (30 semester credit hours) and includes a comprehensive final exam taken in the last semester of the program. The MEA degree has no residency requirement and is available to students not located on the main campus in Blacksburg or the National Capital Region/Northern Virginia Center campus in Falls Church. It is ideal for individuals who are employed full-time and wish to pursue an advanced degree on a part-time basis; however, full-time employment is not obligatory for admission to the program. Classes are typically offered during late afternoon and early evening hours with occasional classes on weekends.

Program Course Requirements

I. <u>**Core Courses**</u> *(One course is required from each of the six topics listed)*
   – **Management of Technological Innovation** (*ISE 5164 Transfer and Application of Emerging Technology*)
   – **Project, Program and Portfolio Management** (*ISE 5174 Engineering Program and Project Management*)
   – **Decision Analysis** (*ISE 5104 Introduction to Operations Research or an appropriate course in quantitative decision making with approval of faculty advisor*)
   – **Management of Capital Investments** (*ISE 5434 Economic Evaluation of Industrial Projects*)
   – **Service and Product Quality** (*ISE 5124 Management of Quality and Reliability*)
   – **Strategic Management of Engineering Enterprise** (*ISE 5114 Case Studies in Engineering Administration*)

II. <u>**Selective Electives**</u> *(One course each is required from any three of the five topical areas)*
   – **Statistical Methods** (*STAT 5615 Statistics in Research or an appropriate course on statistical methods with approval of faculty advisor)*
   – **Enterprise Information Systems** (*ISE 5134 Management Information Systems*)
   – **Enterprise Operations Measurement and Improvement** *(ISE 5144 Productivity and Performance Measurement and Evaluation or ISE 5015 Management of Change, Innovation, and Performance in Organizational Systems I or ISE 5016 Management of Change, Innovation, and Performance in Organizational Systems II)*
   – **Human Systems Integration** (*ISE 5154 Applied Human Factors Engineering or *ISE/CS 5714 Usability Engineering*)
   – **Production Management** (**ISE 5204 Manufacturing Systems Engineering*)

*Note: These courses are typically available only on the main campus in Blacksburg.

III. <u>**Elective**</u> (*One course is required from any one of the three topics listed***)
   – **Design and Leadership of Teams** (*MGT 5314 Dynamics of Organizational Behavior or MGT 5804 Leadership in Technology-Based Organizations or PAPA 5315 Behavioral Skills for Managers*)
   – **Science and Technology Policy** (*PAPA 5614 Introduction to Science and Technology Policy*)
   – **Engineering of Complex Systems** (*ENGR 5004 The Systems Engineering Process or ENGR 5104 Applied Systems Engineering or an appropriate course in science, technology, or engineering with approval of faculty advisor*)

**Note: An alternative course not related to the above topics may be approved by the student's faculty advisor.

A Graduate Certificate in Technology Management can be earned by completion of all of the following four courses:
– ISE 5164 Transfer and Application of Emerging Technology
– ISE 5174 Engineering Program and Project Management
– ISE 5154 Applied Human Factors Engineering
– ISE 5134 Enterprise Information Systems

Transfer Courses
Coursework taken at other universities may substitute for comparable courses on the student's approved Plan of Study. The Virginia Tech Graduate School permits a maximum of 15 semester credit hours to be transferred from universities participating in the Commonwealth Graduate Engineering Program (CGEP). These universities include University of Virginia, George Mason University, Virginia Commonwealth University and Old Dominion University. Alternatively, a maximum of 6 semester credit hours can be transferred from universities outside CGEP, with a maximum of 15 semester credit hours taken at universities other than Virginia Tech.

Requests for transfer credit must be submitted to the MEA Program Director (kharmon@vt.edu) and MEA Program Advisor (pcuren@vt.edu) and must include: a catalog description of the course to be transferred, identification of the course to be substituted, and the actual course syllabus used for the transfer course (that specifies textbook(s) used and assignments). Courses for which the grade earned is lower than a B are not eligible for transfer credit.

MEA Comprehensive Examination
In addition to the 10 courses (30 semester hours), the student must pass a written comprehensive examination. The MEA Comprehensive Exam is a four-hour, open-book, written exam administered every fall and spring semester, usually in April and November. Students must have completed or be scheduled to complete all course requirements in the semester that the exam is taken. This is a proctored exam that may be taken at any site of the student's choosing. Most libraries and educational institutions offer proctoring services free of charge. A proctor must be approved by the MEA Program Director.

Degree Completion
To receive the MEA degree, all students must complete the following:
• have an approved MEA Plan of Study;
• be registered in the semester they wish to have the degree awarded. If not taking courses, submit a "Start of Semester Defense Exception Request" form to the Graduate School;
• submit the Application for Degree through Hokie Spa;
• schedule a Final Examination* through the electronic scheduling system on the Graduate School's website.

The Graduate School uses the student's Final Examination* results to confirm that a student has completed all degree requirements before awarding the MEA degree. The final exam scheduling process requires that a student select a date, time, and location for the final exam; however, the

student is **not** required to be present at the Final Exam location on the selected date. On the scheduled date of the Final Exam, the student's advisory committee will conduct a final evaluation of the student's record to confirm degree completion and then electronically submit a vote of "satisfactory" or "unsatisfactory."
**Note: the Final Examination is separate from the MEA Comprehensive Exam.*

<u>MEA Program Director</u>

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7. SYSTEMS ENGINEERING

Systems engineering is an interdisciplinary field that integrates many different engineering specialties into a total engineering effort to ensure an efficient and effective product (system) output. Systems engineering analyzes the operational needs of industrial, business and government enterprises and by applying scientific and engineering technology develops the integrated hardware and software required to meet those needs. A major feature of systems engineering is its concern for the complete life cycle of the system, from planning, design, development, testing and production to operations, sustaining maintenance and support, and system retirement. Within this broad spectrum, many different categories of systems are in use today, and the complexities of design, production, operations and support vary significantly. A systems engineer is one who can apply the team approach to the process of bringing systems into being and can define their various components, identify and integrate the engineering disciplines needed to develop them and understand the system's operational and maintenance requirements for the entire customer-use period.

Program Description

Based on over 40 years of experience, Virginia Tech continues the tradition of bringing systems engineering and systems thinking to practicing professionals in distributed learning environments. Virginia Tech offers a flexible graduate engineering program to enhance the student's personal/professional development and contributions to the workplace. Some students pursue this degree as a full-time student while many in our program have a full-time job and are taking one, two, or three courses in a semester. For full time students it is possible to finish

the degree in three semesters. Typically, part-time students take one or two courses per semester and no courses in the summer and finish in three or four years.

The Systems Engineering graduate program leads to a Master of Science degree. It is designed to enable engineering practitioners in specialized fields (e.g., aeronautical, ocean, civil, electrical, mechanical and industrial engineering) to develop an interdisciplinary approach to the practice of professional engineering. It is presumed that a student entering the program already has a solid foundation in some specialized field of engineering (or the equivalent) and wishes to broaden his or her technical knowledge base. In addition to core systems engineering and discipline-centric engineering courses the program includes a capstone course requiring the completion of an approved systems engineering project that demonstrates the student's understanding of technology integration, life-cycle design, and collaborative engineering considerations. The objectives of the required capstone experience are to instruct and coach the systems engineering approach as applied in the design and ongoing improvement of any system, enterprise, process or enabling technology.

The program objective is to present a broad interdisciplinary perspective of systems and the numerous considerations necessary in the engineering development of systems. Program requirements include the successful completion of a minimum of 10 courses (30 semester hours) with a B average or better. Upon completion of ten courses with a B average or better, including a capstone project course, the student receives a master's degree in systems engineering.

Course Requirements

I. The following four courses (9 hours) are required for all Systems Engineering students
- ENGR 5004 Systems Engineering Process
- ENGR 5104 Applied Systems Engineering
- ENGR 5204 Systems Engineering Project

II. Three courses (9 hours) in one traditional discipline in science or engineering*

III. Three courses (9 hours) in a second traditional discipline in science or engineering*

*Note 1. Courses in sections II and III must be separate disciplines in engineering or science, other than Systems Engineering. Courses in science/engineering disciplines offered by accredited programs in other universities can be proposed by the student for inclusion in their plan of study as transfer courses, subject to current policies of the Virginia Tech Graduate School and approval of the student's advisory committee.

*Note 2. Subject to availability, a maximum of two (2) ENGR 5984 special study systems engineering courses (6 hours) may be substituted for traditional discipline science and engineering courses in II and III above. However, each plan of study must include a minimum of two (2) courses each in two different science and engineering disciplines.

IV.   One course (3 hours) taken outside of science or engineering (a course in Organizational Dynamics, or Design and Leadership of Teams is highly recommended)

Plan of Study and Degree Completion

An advisory committee is required and the committee will grant final approval of the course work by signing the plan of study form. The plan of study must be completed and approved prior to the completion of 12 hours of course work.

To receive the degree all students must:
- have an approved plan of study
- be registered in the semester they wish the university to confer their degree
- submit an on-line "final exam" request to the Graduate School. This "final exam" request is used by the advisory committee and extended-campus advisor to verify that the student has completed all degree requirements including the capstone course presentation.

Once the final grades for the final semester have been posted the degree will be awarded.

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